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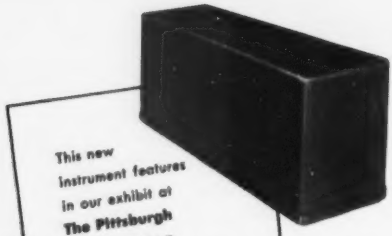

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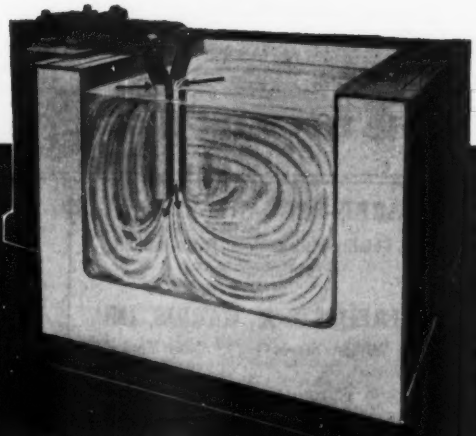

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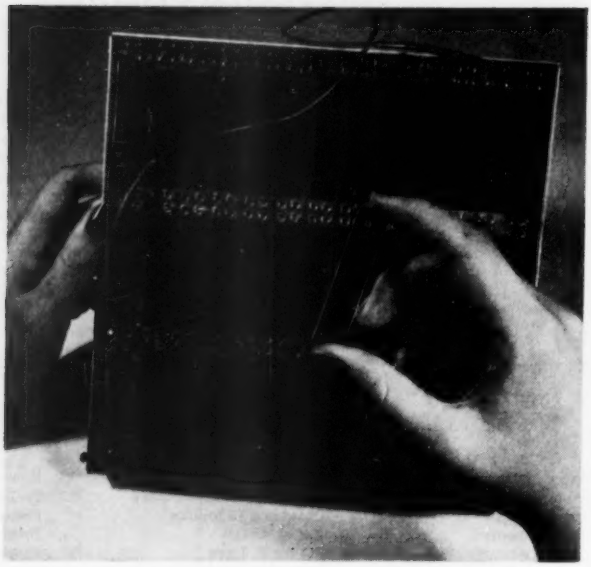

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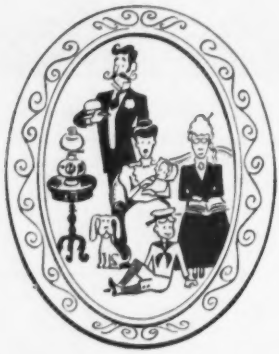

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AN EARLY MARINE STEAM TURBINE PROPOSAL

BY

H. PHILIP SPRATT [1]

More than half a century before Sir Charles Parsons achieved his spectacular success with the *Turbinia* at the Spithead Naval Review in 1897, two other British inventors, Messrs. Cordes and Locke, had obtained 32 brake h.p. from their experimental steam turbine. In 1846 the partners constructed a detailed scale model to show the marine application of their turbine in a vessel of about 700 tons; and this historical exhibit has now been presented by Mr. J. L. B. H. Cordes, F.R.S.A., to the national collections at the Science Museum in London. It represents one of the earliest practical schemes for marine steam turbine propulsion; but before we proceed to describe this machinery in detail, a very brief historical review may not be out of place.

That steam produced from water, when heated, would issue with considerable force from a small aperture in the container, was known to the Ancients. The principle had, in fact, been utilized in the æolipile of Heron of Alexandria (1)[2] about A.D. 50; and Philibert de L'Orme had proposed the use of an æolipile to force smoke up a chimney (2). Other applications of the æolipile are described (3) by Salomon de Caus, of Normandy, who seems to have been about the first, in 1615, to comprehend the enormous power of steam; a force that could move vehicles on land and *ships at sea*. Here can be discerned what is perhaps the first fanciful idea of the steamship.

More mature plans for a steam turbine came from Giovanni Branca, an architect of Loretto, who in 1629 published (4) the description of such a machine. The water was heated in a closed vessel, and the steam was directed from a tube with impulsive effect onto radial vanes formed on the rim of the wheel. This was mounted on a vertical shaft, with a

[1] Deputy Keeper, The Science Museum, London, England.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

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toothed pinion at its lower end. The power is said to have been used to work pestles or stampers in chemical mortars. There is no record that Branca ever considered the problems of ship propulsion; but one of his compatriots, Serafino Serrati of Florence, did contrive to move a small model boat on a pond by means of hot-air reaction, about 1787 or earlier (5).

Other steam turbines on the principles of Heron or Branca included those of Kircher (6) in 1643, Daslesme in 1699, W. von Kempel (7) in 1785, James Sadler in 1791, and Richard Trevithick in 1815. These are all mentioned by an eminent naval architect (8), who denounced the rotatory machine as "false in its mathematical principles, and fallacious as a mechanical structure."

John Stevens, of Hoboken, N. Y., a famous American steamboat pioneer, had in 1802 fitted a 25-ft. flat-bottomed boat with a screw propeller at the stern. To avoid the "mischievous" inertia effects of an alternate to-and-fro piston mass, the screw propeller was direct-coupled to a small rotary steam machine. This comprised a cylindrical chamber of brass, about 8 in. in diameter and 4 in. in axial length (9), in which (mounted on the screw shaft) ran a simple form of two-bladed rotor. Colonel Stevens obtained a speed of 4 miles per hour, but was not satisfied with the experiments until he had replaced his rotary machine by an orthodox steam cylinder and piston.

About this time Oliver Evans, of Philadelphia, had tried an æolipile on the same principle as Heron. The rotary tube was 3 ft. long, which means that each arm had an 18-in. radius. The steam apertures were 0.2 in. in diameter, or 0.063 sq. in. in total area. Supplied with steam at 56 psi. pressure, the machine made between 700 and 1000 rpm.; and, in the inventor's own words (10), it exerted "more than the power of two men."

Another steam reaction turbine on the Heron principle was developed in the United States about 1833 by the American inventor William Avery, of Syracuse, N. Y. His first experimental machine (11) had two rotary arms with 18-in. radius; the steam apertures at their outer ends had a total area of 0.125 sq. in., and moved in a circumference of 113 in. The boiler had a surface of 69 sq. ft. exposed to the fire, which consumed half a cord of wood per day. The steam pressure was 80 psi., and the machine developed about 9 brake h.p. at 4000 rpm. Mr. Avery used it for 18 months to drive his workshop.

In 1834 a British patent (12) for the Avery steam turbine was obtained by Mr. Alexander Craig, who developed it in partnership with Mr. John Ruthven, of Edinburgh. An experimental machine of 15 brake h.p. was constructed (13), in which "the steam is conveyed by a pipe to a hollow axle; on this axle two arms are fixed; these are also hollow, with apertures into the axle to allow the steam to pass from the axle into the arms; and at the end of each arm is an aperture through

which the steam is discharged at right angles to the arms." In this turbine, the two arms were of 30-in. radius (14), and made 3000 rpm.; it was described as "one of the happiest applications of steam power." Subsequent improvements in the Avery reaction steam turbine were proposed about 1845 by Mr. James Black in the United States (15).

Meanwhile, the achievement of a practical steam turbine on the impulse principle of Giovanni Branca seems to have been due to British enterprise. In 1840 the partners James Jamieson Cordes and Edward Locke, both of Newport, Monmouthshire, obtained a patent (16) for a "new rotary engine." This was to consist of a revolving wheel enclosed in an exhausted chamber, and put in motion by the direct action of a current of steam entering the chamber tangential to the circumference

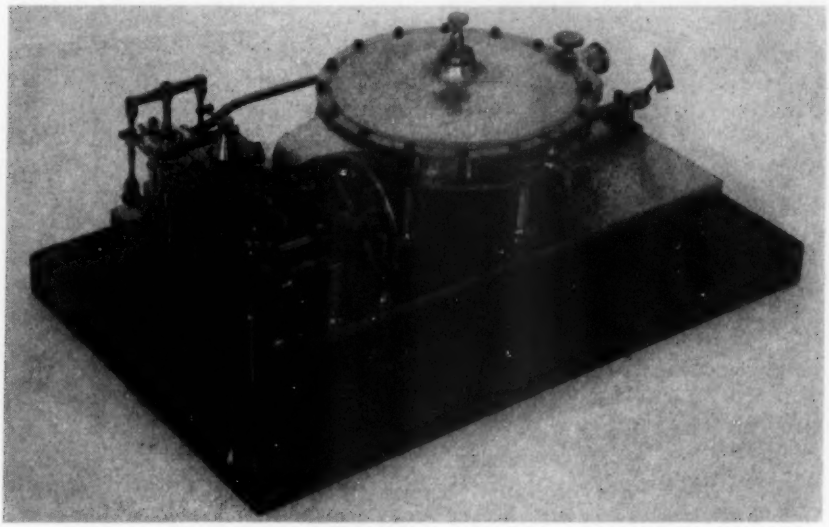

FIG. 1. Model of Cordes and Locke's proposed marine steam turbine (1846). Forward view, with condenser air pumps.

of the wheel, and impinging against suitable vanes affixed to that circumference. The steam was exhausted from the chamber into a condensing apparatus. The power developed by the turbine was to be communicated from the axle of the wheel to any millwork or machinery which it was intended to drive. The patent contained no explicit mention of ship propulsion.

Soon afterwards, a more detailed technical description was published (17). The turbine casing was made of cast iron in two parts, fastened by nuts and bolts, and provided with stuffing boxes for the rotor shaft. The rotor was built up of wrought iron, and the vanes mounted on the rim were of copper, set at a suitable angle. The steam was admitted by a throttle valve, and after striking against the vanes, was exhausted

to the condenser. The rotor shaft carried toothed gearing to drive any millwork or machinery, also a mitre wheel for the turbine governor to control the steam throttle valve and thereby the speed of the turbine. Cold water circulation was to be used for cooling the main bearings of the rotor shaft.

In 1846 the partners, Messrs. Cordes and Locke, constructed their small rotary machine, or steam turbine, at the Surrey Docks, Rotherhithe, for experimental purposes. The rotor was 11.6 ft. in diameter, mounted on a horizontal shaft, and built up with 28 radial arms and

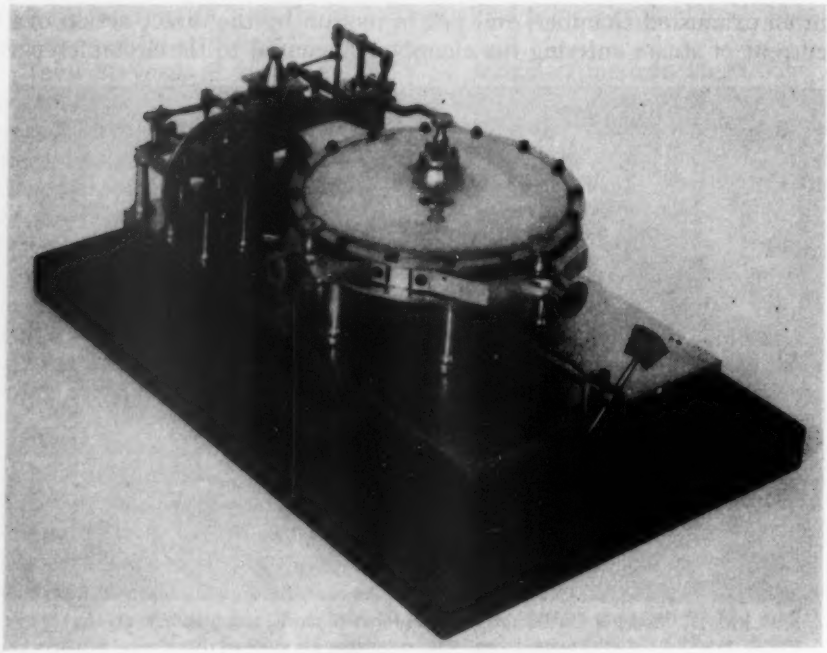

FIG. 2. Model of Cordes and Locke's proposed marine steam turbine (1846). Aft view, with screw shaft and propeller.

vanes. The breadth of each vane was 6 in., and the depth 7 in.; the vane area was thus 42 sq. in. The steam orifice was of oval shape, 3 in. by 2 in., and was set vertically. The report (18) of Mr. Josiah Parkes, C.E., who was appointed to test the turbine, states that it developed 32 brake h.p. at 502 rpm. The boiler pressure was 2.75 psi. above atmospheric, and a vacuum of 27.2 in. was maintained inside the wheel-case. The evaporation of water amounted to 100.5 lb. per brake h.p. per hour.

The marine turbine proposal of 1846 is represented in detail by the contemporary model shown in the illustrations. This is beautifully

constructed in brass, to a scale of 1:64. It shows a rotor 19 ft. in diameter, with copper rims built up on six radial arms, and mounted on a vertical shaft. Between the rims were placed 18 radial copper vanes, each 18 in. wide and 18 in. deep; the vane area was thus 324 sq. in. This turbine had two oval-shaped steam orifices 4.75 in. by 3.12 in. for ahead motion, and two others for astern, all set horizontally. The orifices were mounted in pairs, one ahead and one astern, for each of the two steam inlet pipes from the boiler. Reversal was effected by means of two semi-rotary two-way cocks, one to each steam inlet, which controlled the distribution to the respective ahead or astern orifices as required.

The turbine was intended to develop 150 brake h.p. at 300 rpm., with a boiler pressure of about 3 psi. above atmospheric. The two vertical air pumps for the condenser (see Fig. 1) were each 45 in. in diameter with a 24-in. stroke, and were driven by side-levers and one vertical steam cylinder 33 in. in diameter with a 48-in. stroke. The side-levers also had vertical arms and connecting-rods to drive a crank-shaft with flywheel 10 ft. in diameter, which served to carry the pumps over the dead centre. About 27.2 in. of vacuum was anticipated inside the turbine case.

The lower end of the main rotor shaft carried a pinion of 30 teeth, which meshed with a bevel wheel of 60 teeth mounted on the horizontal propeller shaft. This was intended to run at 150 rpm., and is shown fitted with a two-bladed screw propeller 10 ft. in diameter (see Fig. 2), for a small wooden-hulled coastal vessel of about 700 tons: length, 165 ft.; breadth, 31 ft.; depth, 16.5 ft.; draught, 13.5 ft. The speed (under sail and steam) would not have been more than about 9 knots.

The practical success of Messrs. Cordes and Locke's experimental turbine must have raised their hopes of its application, at least as an exhaust-steam turbine, to marine propulsion. No record has been found, however, that it was ever fitted into a vessel; and so the pioneer honours for the first marine steam turbine (19) fell to Sir Charles A. Parsons at a much later date.

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A NEW HOMOPOLAR MOTOR

BY

Y. H. KU [1] AND AHMAD KAMAL [1]

SYNOPSIS

A new homopolar motor has been designed and constructed based on the principle of the Faraday disk. The magnetic circuit consists of two halves made from Armco iron. The rotor disk is made from a low carbon steel plate. Current is fed to the disk radially through 8 brushes of copper graphite, while 8 other brushes on both sides of the shaft form the output terminal. With 2 volts input voltage and 100 amperes input current, the motor delivers approximately 1/6 h.p. at 5800 rpm. with 50 per cent efficiency. Performance curves and a transient response oscillogram are presented.

INTRODUCTION

Since Faraday's time, the principle of the homopolar *generator* has been well known. The Faraday disk is sometimes called the Lorenz apparatus, as Lorenz used it for the absolute determination of the ohm (1).[2] As Liwschitz remarked (2): "Theoretically it is possible to produce direct current *directly* without resorting to the use of a commutator." Practically, homopolar generators have been built and used recently as tachometers (3).

During World War II, there was an attempt in Germany to make a homopolar *motor*, and a fragmentary description was given by Böning (4). The principle of this design was explained by Professor G. W. O. Howe (5) in November of 1952.

It is the purpose of this paper to describe the design and performance of a new homopolar motor. Except for the Böning and Howe references, there are no recent reports on homopolar *motors*.

THE HOMOPOLAR MOTOR DESCRIBED BY BÖNING

From ref. 4, we find that this design of a homopolar motor as described by Böning consists simply of two iron halves A and B (Fig. 1) forming the magnetic circuit and at the same time the moving part. The energizing coil is made in the form of a spiral which is fixed and thus forms the stationary part. The current is fed from one end as shown by the arrow, transmitted through the contactor D to the iron, and collected at E, which also forms the output terminal. The explanation of the principle of this motor is given in ref. 5.

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[2] The boldface numbers in parentheses refer to the references appended to this paper.

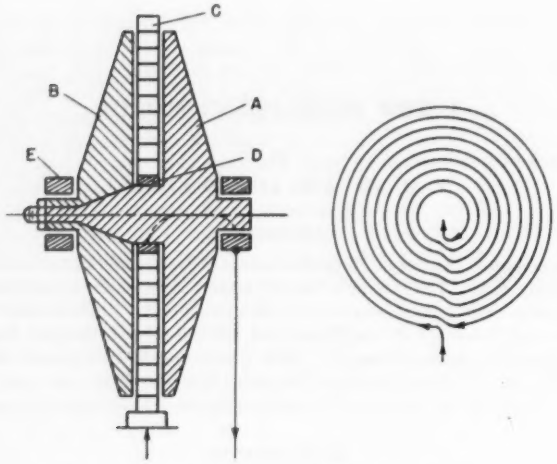

FIG. 1. Homopolar motor described by Böning.

DESIGN OF THE NEW HOMOPOLAR MOTOR

A number of alternative designs have been made for a new homopolar motor. Since the moving part of the motor described by Böning consists of the magnetic circuit, there is difficulty in running at high speed with good efficiency. We have kept the magnetic circuit stationary and used Armco iron to get a flux density of 20,000 gauss (see Fig. 10). The rotor is in the form of a Faraday disk made from a low carbon steel plate of $\frac{5}{8}$-in. thickness and annealed.

The principle of the Faraday disk as a generator is well known. Let the flux lines perpendicular to the disk be represented by ϕ and the flux

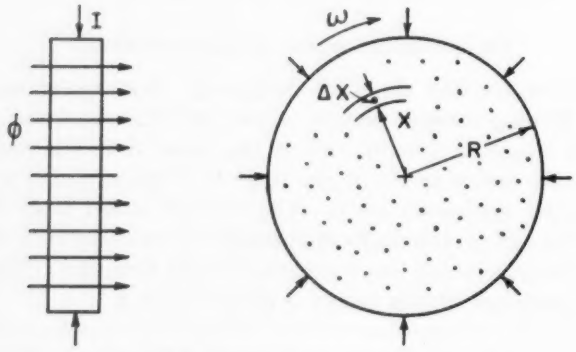

FIG. 2. Faraday disk as a homopolar motor.

density be denoted by B. By the relation $E = Blv$, we have, for $\Delta l = \Delta x$ in Fig. 2, and $v = \omega x$,

$$\Delta E = B v \Delta x = B \omega x (\Delta x) \tag{1}$$

where v = peripheral velocity at a point x from the center of the disk, ω = angular velocity of the disk = $2\pi n$, and n = rps.

The total electromotive force between the axis and the periphery of a disk with radius R is then[3]

$$E = \int_0^R B \omega x \, dx = B \omega \int_0^R x \, dx = \tfrac{1}{2} B\omega R^2 \tag{2}$$

for constant flux density and constant speed of the disk. Since the area of the disk is equal to πR^2, and $\omega = 2\pi$ (rps.) = $2\pi n$,

$$E = \phi n \tag{3}$$

where ϕ is in maxwells, n in revolutions per second, and E in abvolts. For E in volts, the right hand side of Eq. 3 has to be multiplied by a factor 10^{-8}.

Instead of supplying mechanical power to the disk and making it rotate at a speed n, we can supply a current I between the periphery and the axis of the disk. By the relation $F = BlI$, we have, for $\Delta l = \Delta x$ in Fig. 2,

$$\Delta F = B I \Delta x \tag{4}$$

where F = force in dynes, B = flux density in gausses, I = current in abamperes, and x = distance in centimeters.

The torque is given by $T = F x$, or

$$\Delta T = B I x (\Delta x). \tag{5}$$

Integrating, for constant B and constant I,

$$T = \int_0^R B I x \, dx = B I \int_0^R x \, dx = \tfrac{1}{2} B I R^2 \tag{6}$$

or

$$T = \frac{\phi I}{2\pi} \tag{7}$$

where T = torque in dyne-centimeters.

[3] Strictly speaking, the lower limit of the integral should be r, the radius of the shaft of the disk or rotor.

If I is expressed in amperes, ϕ in maxwells, and T in ounce-inches, Eq. 7 becomes,

$$T = 2.255 \times 10^{-7} \phi I \text{ oz. in.} \tag{8}$$

In the present case the actual disk diameter was made 4.22 in. or 10.72 cm. For the radius R equal to 5.36 cm., the area of the disk is 90 sq. cm. Assuming an effective area of 80 sq. cm., and a flux density of 20,000 gausses (lines per sq. cm.), the total flux ϕ is 1,600,000 maxwells or 1.6 megalines. The current supplied to the disk was limited to 100 amperes. So by Eq. 8,

$$\begin{aligned} T &= 2.255 \times 10^{-7} \quad (1.6 \times 10^{6}) \times 100 \\ &= 36 \text{ oz. in.} \end{aligned}$$

For a homopolar motor, the relation $E = \phi n$ given by Eq. 3 may be considered as representing the back emf. So, for $\phi = 1.6 \times 10^{6}$ and $n = 100$ rps. (assumed), $E = 1.6 \times 10^{8}$ abvolts or $E = 1.6$ volts.[4] Since the applied voltage to the disk or the rotor must be greater than the back emf. by the IR drop, where R represents the combined resistances of the rotor and the brushes, V, the input or rotor voltage, will be around 2 volts.

The order of magnitude of the disk resistance can be evaluated as follows:

$$R_D = \int_r^R \frac{\rho dx}{2\pi x(b)} = \frac{\rho}{2\pi b} \ln x \Big|_r^R = \frac{\rho}{2\pi b} \ln \frac{R}{r} \tag{9}$$

where b = thickness of the disk = 0.122 in. = 0.31 cm., R = radius of the disk = 5.36 cm., r = radius of the shaft of the disk = $\frac{5}{16}$ in. = 0.795 cm., and ρ = resistivity of the steel = 17.4 microhm-cm. (assumed). Substituting these numerical values in Eq. 9, we get,

$$\begin{aligned} R_D &= \frac{17.4 \times 10^{-6}}{2\pi\ (0.31)} \ln \frac{5.36}{0.795} \\ &= 8.95 \times 10^{-6}\ (1.9066) = 1.71 \times 10^{-6} \text{ ohm.} \end{aligned}$$

This value is negligible relative to R_B, the resistance of the brushes.

DESCRIPTION OF THE HOMOPOLAR MOTOR

The assembly drawing of the motor is shown in Fig. 3, with details of the magnetic circuit shown in Fig. 4, and details of the rotor (disk) shown in Fig. 5. The actual photograph of the motor is shown in Fig. 6. Two views of the disassembled motor are shown in Fig. 7.

The magnetic circuit consists of two halves made of Armco iron (see Figs. 3 and 4). The iron has a carbon content of 0.015 per cent, silicon 0.003 per cent, and total impurities 0.07 per cent. It has a saturation

[4] This is equivalent to $E = 16$ millivolts/rps.

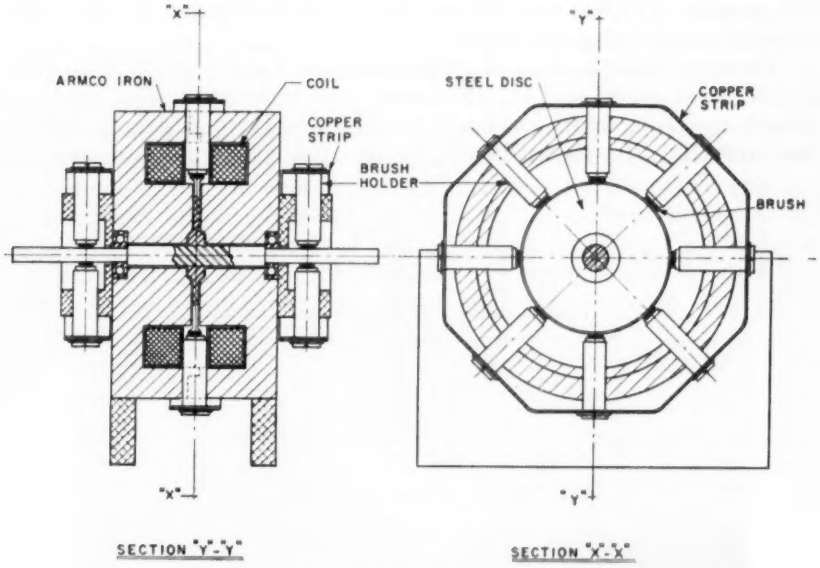

FIG. 3. Design of a new homopolar motor.

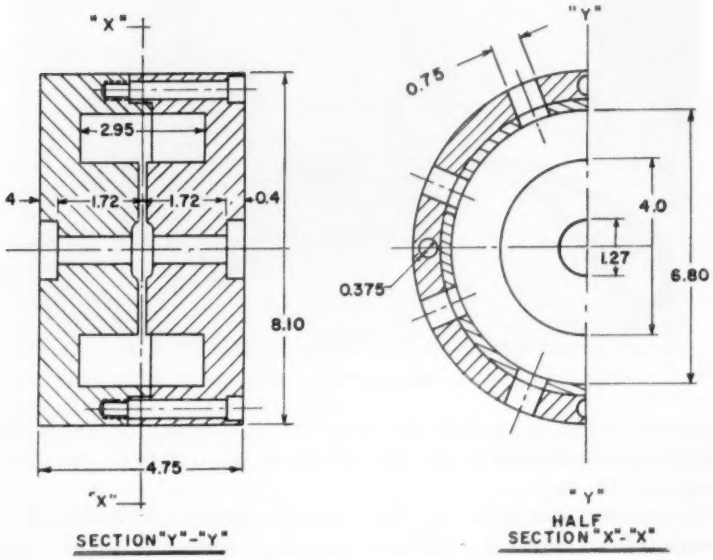

FIG. 4. Details of the magnetic circuit.

flux density of 21,000 lines per sq. cm. It was annealed by the manufacturer before being machined.

The rotor is in the form of a disk (see Figs. 3 and 5) made from a low carbon steel plate of $\frac{5}{8}$-in. thickness, and annealed. The disk was shrunk to a $\frac{5}{8}$-in. shaft, and both the shaft and the disk were ground to the final size. As shown in Fig. 5, the disk was finally ground to a

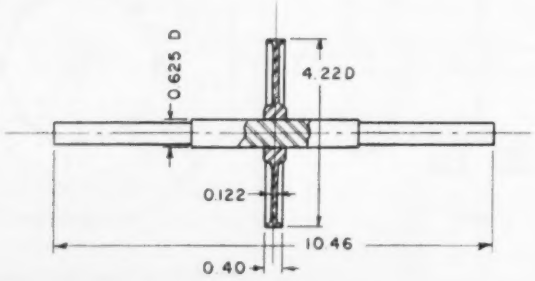

FIG. 5. Details of the rotor.

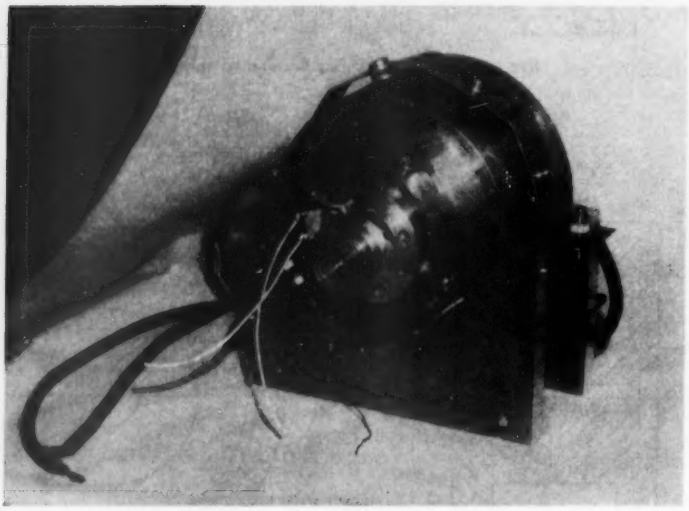

FIG. 6. General view of the motor.

thickness of 0.122 in., a little less than $\frac{1}{8}$ in. The shaft rotates through two bearings imbedded in the two halves of the magnetic circuit. The air gap is 0.010 in.

The current was fed to the disk radially through 8 brushes of copper graphite (86 per cent Cu) which are specified to have very low coefficient of friction, extremely low contact drop and very low specific resistance. Beryllium copper springs were used at a pressure of 2 psi. As shown in

the right side of Fig. 3, these 8 input terminal brushes are connected together by a copper strip. There are 8 other identical brushes arranged on both sides of the shaft and connected also in parallel to form the output terminal.

The field is established by two coils imbedded in the circular space made in the two halves of the magnetic circuit (see Fig. 3). The coils were made of 916 turns of A.W.G. 18 double glass insulated wire and have a total resistance of 8.5 ohms at 20° C. Theoretically it was estimated that with 6 amperes field excitation we can get about 1.4×10^6 flux lines to pass through the disk. Experimentally, we find that with 5 amperes field excitation, we can get ϕ equal to more than $1.6 \times$

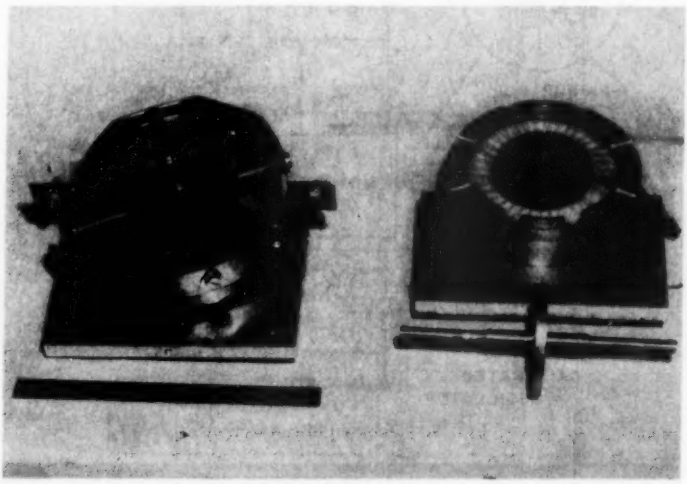

FIG. 7. Motor disassembled.

10^6 flux lines corresponding to a flux density B of more than 20,000 gausses (lines per sq. cm.). The experimental magnetization curve is shown in Fig. 10.

The total weight of the machine is about 75 lb.

DIAGRAM OF EXPERIMENTAL CONNECTIONS

The diagram of connections for the experiment is shown in Fig. 8. A photograph of the setup is shown in Fig. 9.

In Fig. 8, the field or stator circuit is supplied by a 110v. d-c. source. For $R_f = 8.5$ ohms, a voltage V_f equal to 51 volts will give I_f equal to 6 amperes. The rotor or disk voltage V_r is maintained at 2 volts, obtained from an 18v. d-c. source.

The homopolar motor was connected to an electric dynamometer to measure the output torque.

The speed of the motor was measured by mounting a small aluminum

wheel on the shaft on which two small magnets were fixed diametrically opposite as shown in Fig. 8. A small pickup coil was fixed to the frame. The rotation of the two magnets induced an emf. in the coil which was connected to the horizontal input of an oscillograph. A voltage wave from an oscillator was applied to the vertical input of the oscillograph. The frequency of the calibrated oscillator was adjusted until a stationary pattern was obtained. Thus the frequency of the rotation of the motor was determined.

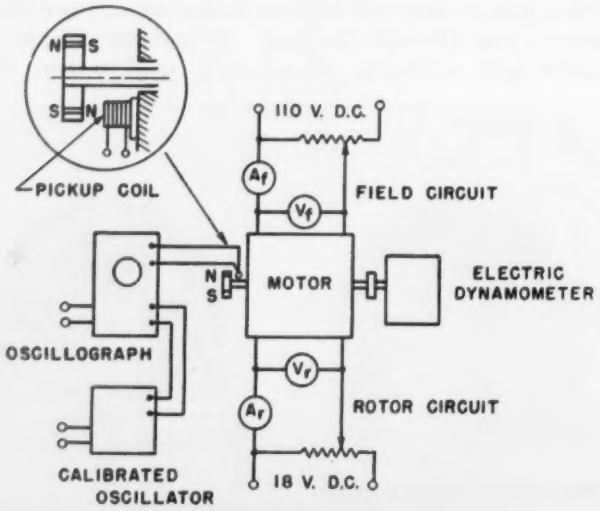

FIG. 8. Diagram of connections.

FIG. 9. Experimental setup.

PERFORMANCE CURVES

The magnetization curve (Fig. 10) was first obtained by driving the machine as a generator at constant speed. The output voltage was measured by a high impedance vacuum tube voltmeter for various field excitation currents. The flux was then calculated. The test was repeated at different speeds as a check. From Fig. 10, it is seen that for $I_f = 4$ amperes, the flux through the disk is 1.6 megalines. For a homopolar generator, since $E = n\,\phi\,10^{-8}$ volts, for $n = 1$ rps., $E = 16$ millivolts/rps. The homopolar generator reported in ref. 3 gives a calculated value of 1.0 millivolt/rps. and a measured value of 1.7 mv/rps.

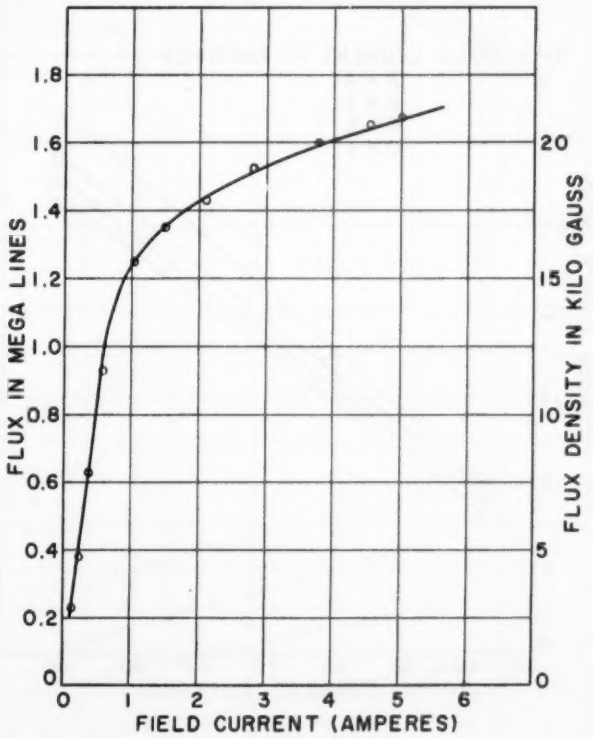

FIG. 10. Magnetization curve.

The saturated flux density is given as between 10,000 and 11,000 gausses. By doubling the flux density, a modified design would give $E = 3.4$ mv/rps. Since the total flux is proportional to the area of the disk, doubling the radius of the disk would increase the generated voltage by 4 times, giving $E = 13.6$ mv/rps., which is comparable to our value $E = 16$ mv/rps.

As torque depends on the product of flux ϕ and the current I through

the rotor or I_r according to Eq. 7, the relation between torque and the rotor current is a straight line, for a given value of ϕ, depending on I_f. Four such lines are plotted in Fig. 11. The torque varies from about 10 oz. in. to 30 oz. in. as the rotor current increases from 40 amp. to 100 amp.

The torque-speed characteristic curves are given in Fig. 12. They are similar to the torque-speed curves of a d-c. shunt machine. For constant I_f and hence constant ϕ, the back emf. E is proportional to the speed n, according to Eq. 3. Now, for constant ϕ, the torque is pro-

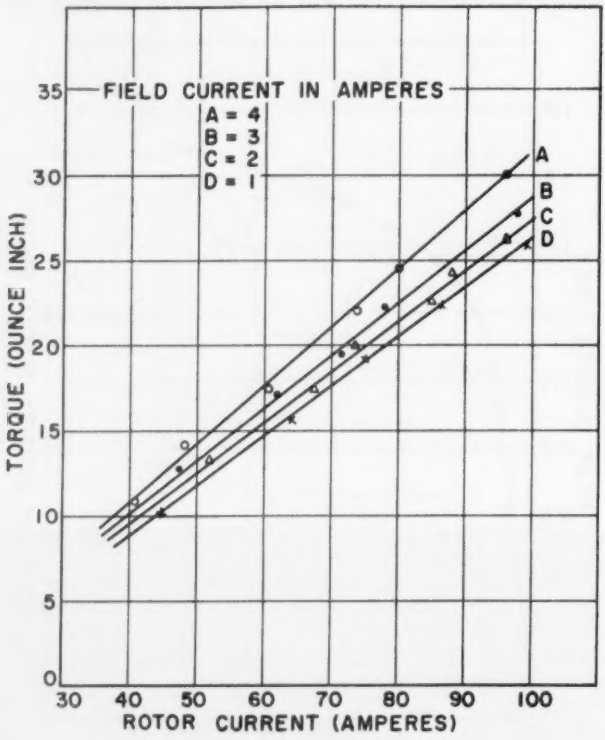

FIG. 11. Torque *vs.* rotor current I_r.

portional to the rotor current I_r, which is equal to $(V\text{-}E)/R$, where V represents the rotor voltage, or V_r, and R the combined disk and brush resistances. Except for possible variations of the value of R, at different speeds, the torque-speed characteristics are essentially straight lines as shown.

For constant ϕ, the speed n is proportional to the back emf. E, which is equal to $(V-IR)$. So, at no load, when the IR drop is small, n is practically proportional to the rotor voltage V_r. The relation between speed and rotor voltage is shown in Fig. 13.

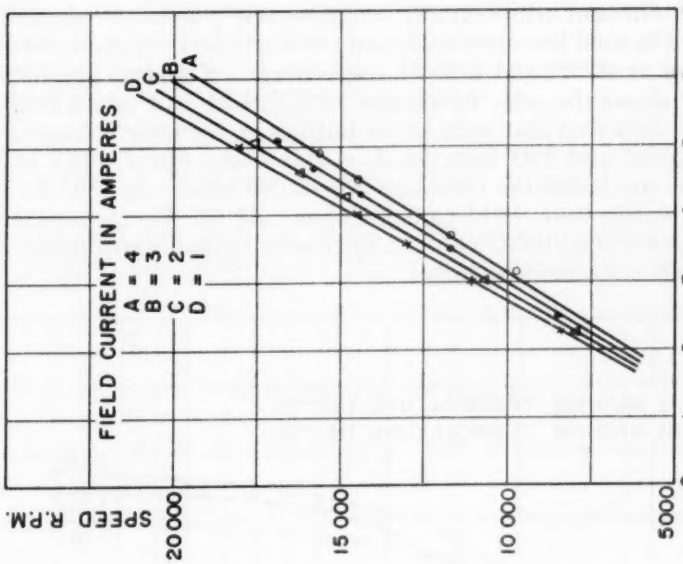

Fig. 13. Speed *vs.* rotor voltage at no load.

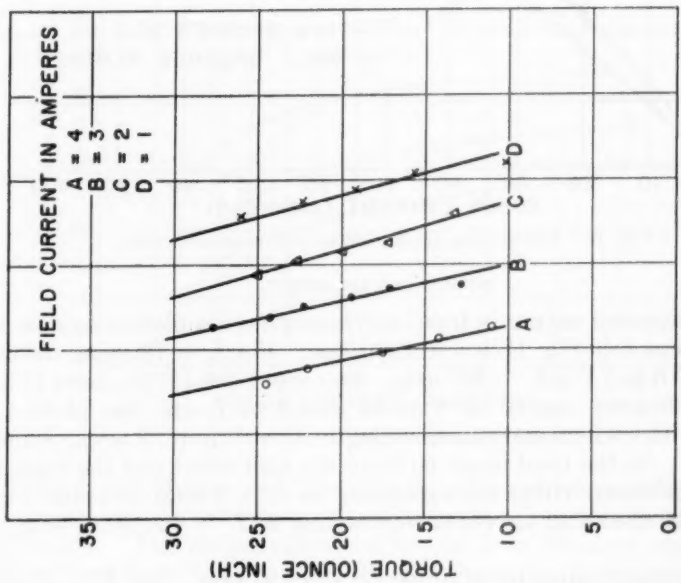

Fig. 12. Torque speed characteristic.

In order to find the relation between the rotor voltage and the rotor current at different temperatures, experimental results are plotted in Fig. 14. The solid line curves (*A*) and (*B*) show the $V-I$ characteristic of the rotor at 65° F. and 150° F., respectively. The dash and dotted line curve shows the same relation at 150° F. with half of the brushes removed. It is seen that with all the brushes in, the rotor voltage drop is between 0.4 and 0.45 volt, for $I_r = 100$ amp. For $I_r = 42$ amp., $V_r = 0.34$, and hence the resistance $R = 0.008$ ohm. At 150° F., the resistance varies from 0.012 to 0.004 ohm. At 65° F., the resistance varies from 0.010 to 0.0045 ohm. Under actual running conditions, the brush resistance should be higher.

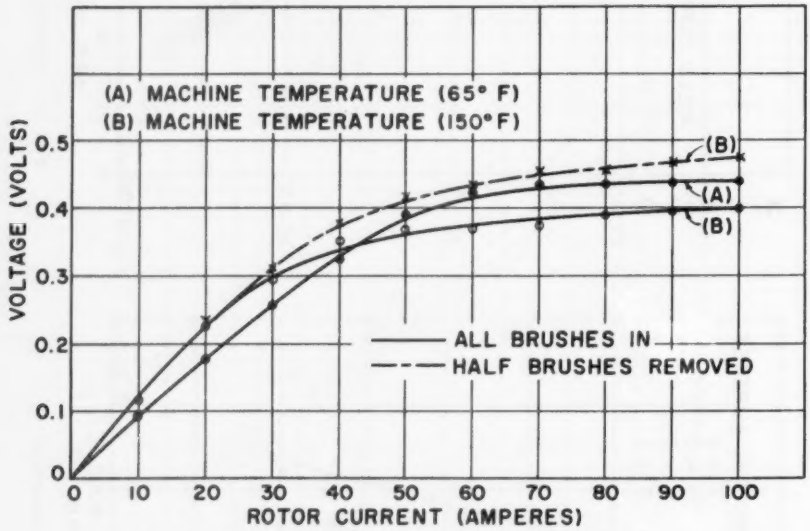

FIG. 14. Voltage-ampere characteristic of rotor and brushes.

OUTPUT AND EFFICIENCY

The measured output in fractional horsepower is plotted against the rotor current I_r in Fig. 15 as a straight line. For $I_r = 70$ amp., the output is 0.10 h.p. For $I_r = 100$ amp., the output is 0.15 (or about $\frac{1}{6}$) h.p.

The efficiency curves for various values of I_r are also plotted in Fig. 15, with excitations corresponding to $I_f = 1$ amp., 2 amp., 3 amp., or 4 amp. As the total input includes the field input and the rotor input, the efficiency curve corresponding to $I_f = 1$ amp. is found to be higher than the other curves corresponding to $I_f = 2$ amp., 3 amp., or 4 amp.

Taking the *D* curve for example, let $I_r = 50$ amp. For $I_f = 1$ amp., the field input is equal to $V_f I_f = I_f^2 R_f = (1)^2\ (10.5) = 10.5$ watts, since R_f at running temperature is 10.5 ohms. Since the rotor voltage is

maintained at 2 volts, the rotor input is equal to $V_r I_r = (2)\ (50) = 100$ watts. The total input is therefore $(100 + 10.5) = 110.5$ watts. From Fig. 11, we find that for $I_f = 1$ amp. and $I_r = 50$ amp., the torque is equal to 11.7 oz. in. From Fig. 12, the corresponding speed is found to be 6060 rpm. The power output is given by

$$\text{H.P.} = \frac{2\pi n\, T}{12 \times 16 \times 33{,}000} = \frac{2\pi(6060)(11.7)}{12(16)\ (33{,}000)} = 0.0704$$

where n is in rpm. and T in oz. in. This corresponds to an output of 52.5 watts. The efficiency is therefore equal to 47.5 per cent.

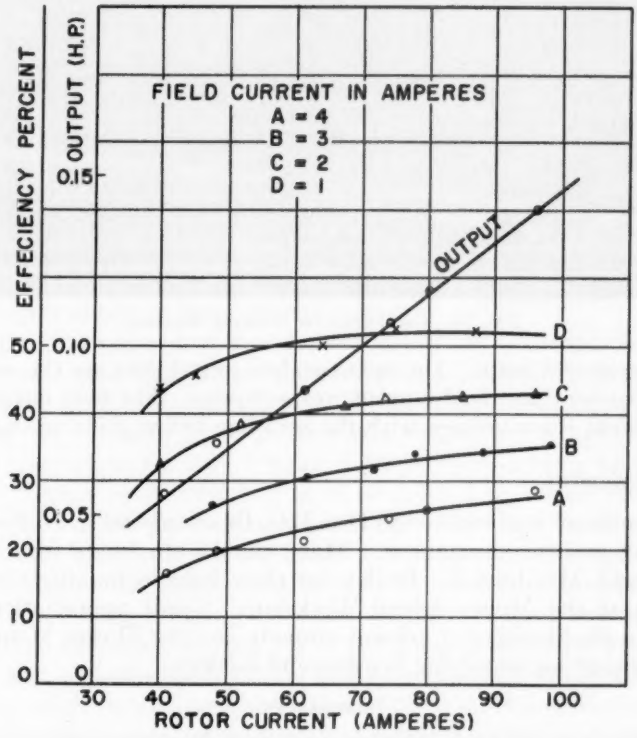

FIG. 15. Output and efficiency curves.

Take $I_r = 100$ amp. and $I_f = 1$ amp. The field input is 10.5 watts. The rotor input is now increased to 200 watts. The total input is then 210.5 watts. The torque corresponding to $I_r = 100$ amp. and $I_f = 1$ amp. is found from Fig. 11 as 26.4 oz. in. From Fig. 12, the corresponding speed is 5800 rpm. So the power output is 0.1515 h.p. or 113 watts. The efficiency is therefore equal to 53.7 per cent.

TRANSIENT RESPONSE

The oscillogram for transient response is shown in Fig. 16. The first (top) curve shows the variation of speed with time. The second curve shows the transient rotor current. The third curve shows a steady

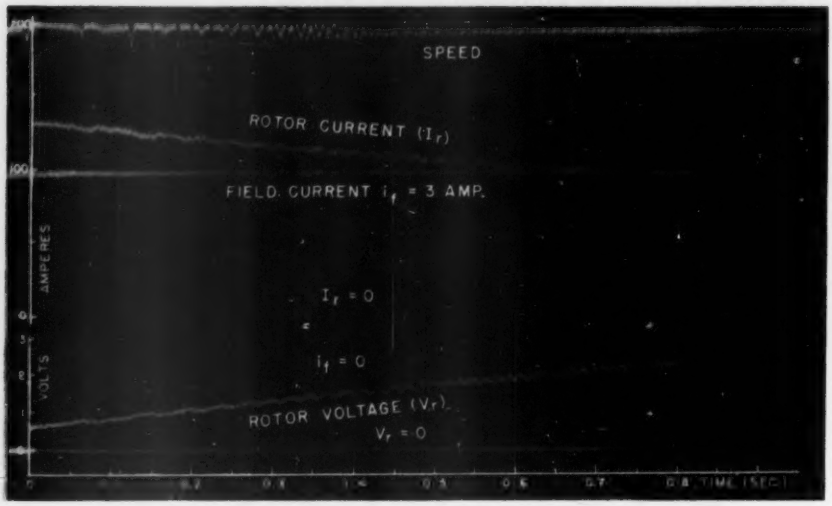

FIG. 16. Oscillogram for transient response.

field current of 3 amp. The next two horizontal lines are the zero lines of rotor current and field current, respectively. The next curve shows the transient rotor voltage with the zero line below (bottom curve).

Acknowledgment

The authors are indebted to Drs. J. G. Brainerd and C. N. Weygandt for advice and encouragement. Many thanks are due to Mr. Miles E. Nelson and Mr. John H. Pedley for their help in making the model machine at the Moore School Workshop. Great appreciation is extended to the Stackpole Carbon Company and the Flower Manufacturing Company for supplying brushes and holders.

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A NEW PRESSURE-SENSING INSTRUMENT *

BY

WALLACE E. FRANK [1] AND ROBERT J. GIBSON [1]

ABSTRACT

A new pressure-sensing instrument involving capacity changes has been developed. Arrays consisting of a number of these "Filpips"[2] have been constructed and connected to simple electronic measuring instrumentation. Generally, reproducibility within 10 per cent is obtainable.

I. INTRODUCTION

This paper describes work done in developing a system for measuring the pressure which is exerted by an individual on his environment. The requirements are that the range of sensitivity shall be the same as that expected to exist between an individual and the ground on which he may be lying or various portions of his clothing or equipment; the interposition of the pressure-sensing elements should not appreciably change the load distribution; and relatively high geometric resolution should be possible so that accurate pressure contours may be drawn, particularly in the neighborhood of bony prominences.

The original concept of such a system basically covered the use of an array of pressure-sensing elements of capacitor or resistance type, mounted in a flexible blanket electrically connected to instruments which measured the changes in their electrical properties as the result of external mechanical forces. Two of these pressure-sensing blankets or arrays of Filpips, each consisting of 18 elements 1 sq. cm. in area and 1 in. between centers, have been constructed. Also developed and constructed have been unit electronic accessory boxes containing an oscillator, a bridge, a measuring instrument and necessary accessories for use with the pressure-sensing elements. Attempts have been made to manufacture the units so that all of the pressure-sensitive capacitors may be used with the same bridge to secure readings which are within 10 per cent of the actual pressure. One of these units is shown in Fig. 1. While the present units are sufficiently advanced for many applications, other schemes are under development for further reducing the error resulting from hysteresis.

* This work was done under contract with the Department of the Army, Pioneering Research Division, Philadelphia Quartermaster Research and Development Laboratory.

[1] Bioengineering Section, The Franklin Institute Laboratories for Research and Development, Philadelphia, Pa.

[2] Franklin Institute Laboratories Pressure Indicating Patch.

II. DEVELOPMENT

A. Rubber and Plastic Dielectrics

The most obvious design consisted of a simple sandwich with conductors on top and bottom and a compressible dielectric between. Such a design, using thin sheets of soft rubber and plastic between foil, proved impractical, however, because the change in capacity was so small that measurement of load by this method was not easy.

It seemed, then, that a less rigid sandwich was needed since the "spring" between the conducting plates was too hard. In order to change the spring, some of the material supporting the load was removed, by punching many holes in the rubber sheet. This reduced the load-bearing surface and increased the unit compressive stress in the dielectric. Over-all condenser characteristics were not changed very much.

Another approach to the problem was to resist the force by bending

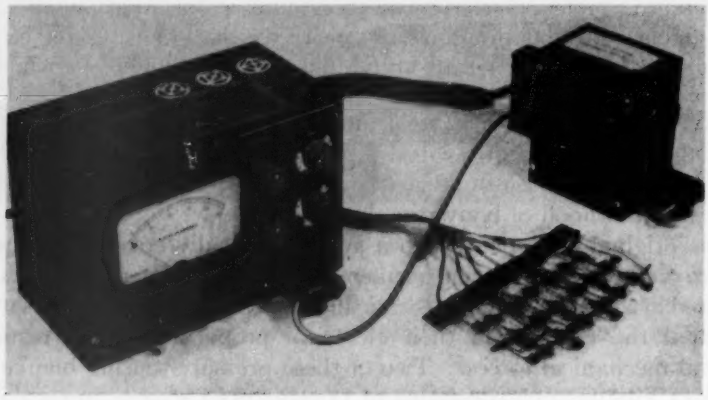

FIG. 1. Eighteen-element Filpip array and associated equipment.

rather than compressing the material. This was done in several ways: (1) the dielectric between conducting layers was deformed into a waffle shape; (2) the conducting metal sheets were deformed into a waffle shape and used as structural elements; and (3) actual cantilever springs were stamped into the conducting sheets. All of these methods were fairly successful.

In the production of the deformed shim-stock condenser plates, simple dies of hardened steel were used against 1-in. thick rubber in a small arbor press. It was found unnecessary to produce a perfectly shaped tooth on the die since pressing the die against the metal directly caused tearing and splitting; instead, several layers of thin plastic were used between the die and the metal to be formed. This had the effect of smoothing the die and produced an excellent impression in the shim stock.

In order to simplify the electrical measurement problem and to minimize errors due to stray capacity, a standard multi-plate condenser construction was selected This standard construction consisted of seven layers of conducting material, four plates grounded, three plates insulated. The sensitive area was about one square inch in this first model.

The number of capacitor plates used does not change the fractional sensitivity. Each pair of plates changes its capacity a certain fractional amount with a change in pressure. When more plates are added physically they are added in series with respect to the applied pressure (each one carries the full load) but they are connected in parallel electrically and thus the fractional change of a multiple-plate capacitor is the same as that for a two-plate capacitor. Since the zero load capacity of one pair of plates is fairly small and is comparable to the lead capacity connecting the capacitors to the measuring bridge it is advantageous to use more than the minimum number of plates. Thus the cable capacity does not have as large an effect and the absolute capacity change is larger and is easier to measure accurately on the measuring bridge.

In order to shield the capacitor itself, an odd number of plates is used and the outer plates are grounded. The outer plates then shield the inner plates and the grounded plates may be touched by the body with only a negligible change in the measured capacity.

The chief problems to overcome were instability of zero reading, slow drift with continued loading, slow exponential-type return to zero when load was removed and poor sensitivity.

One of the early types which showed promise was soft sheet-rubber as dielectric and half-hard aluminum foil embossed with a pyramidal pattern about $\frac{1}{16}$ in. square. However, even when soft rubber was used in thin sheets and compressed by flat plates it was too stiff. Small holes were then punched as close as possible over the entire area of the rubber sheet. Some small decrease in the stiffness resulted. Capacitors using a dielectric of deformed polyethylene were then tried. By applying pressure to a sandwich of rubber, window screening, polytheylene and rubber a good deformation pattern was obtained in the polyethylene. Later some polyethylene was obtained, embossed with a diamond pattern and a square pattern. Finally brass forming dies were made. A typical unit using these dies consisted of seven layers of flat metal plates approximately $\frac{1}{2}$ in. in diameter. The dielectric was polyethylene and was deformed by a die made for the purpose. The deformation consisted of a square array of truncated pyramids about $\frac{1}{32}$ in. square. The unit was fastened together around the circumference of the dielectric material by heat sealing.

B. Printed Circuits

An off-shoot of the technique described above was the use of plastic (vinyl or saran) in place of metal conductors. The plastic was painted

with a commercial silver conducting paint composed of fine pure silver flakes with an air-drying binder and butyl acetate as a thinner. The conducting paint was applied by the silk-screen process, using a screen having nine discs ½ in. in diameter, with leads to the edge.

An experimental blanket-type array (Fig. 2) was constructed, using the deformed plastic with printed conductors and leads. The layers of the blanket were heat sealed. However, these units and blankets with plastic sheets had two disappointing characteristics—creep under load, and hysteresis. (Hysteresis here means that the capacity was lower

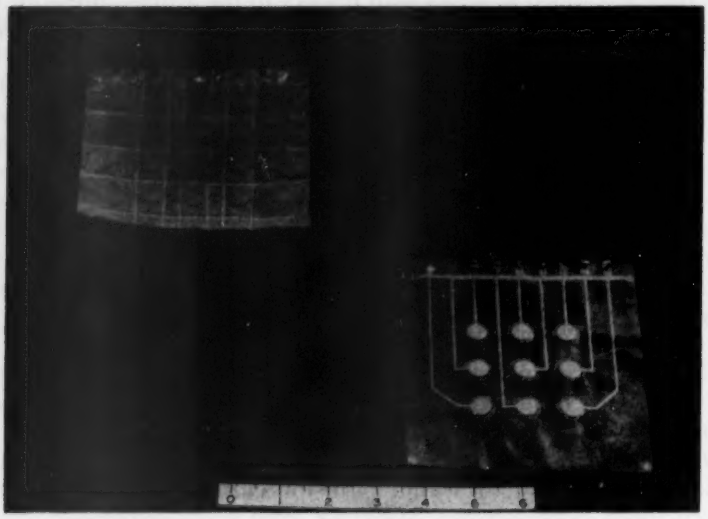

FIG. 2. Early silk screen plastic blanket arrays.

for an increasing load than for a decreasing load at the same load.) Both of these were of such a large magnitude that the use of plastic was abandoned since all attempts to remove the creep and hysteresis failed at that time.

C. Mica Dielectrics

At the next stage of development, work was concentrated on removing the hysteresis. Condensers, using no plastic or plastic-like materials, were designed of metal (0.001-in. steel shim stock) and mica. A fairly good grade of mica (clear, transparent) was split by hand to thicknesses ranging from 0.0005 in. to 0.002 in. A standard area of 1 sq. cm. was chosen as a practical size for the conducting plates. Nearly one hundred and fifty condensers were made with two variables: (1) configuration of the metal deformation and (2) the mica thickness. The types of deformation tried were "waffle" (two sizes of small truncated pyramids 0.030 in. and 0.050 in.), corrugations (two sizes, wavelengths

about 0.045 in. and 0.180 in.) and circumferential corrugations (two sizes, wavelength 0.045 in. and 0.090 in.). Steel waffles (0.030 in.) with mica 0.0009 in. to 0.0013 in. were found to give condensers which had a useful pressure-sensitive range from 0 to 50 psi.

The response of these condensers to loading was not linear—a sharp rise preceded a fairly linear section. It was reasoned that by putting an initial load on the capacitors the response could be made linear. Therefore small cantilever springs were punched from a plate of 0.0015-in. spring steel feeler-gauge stock and the capacitor assembled with these springs under load. This proved successful and the response curves then did not have the sharp rise at low loads (Fig. 3).

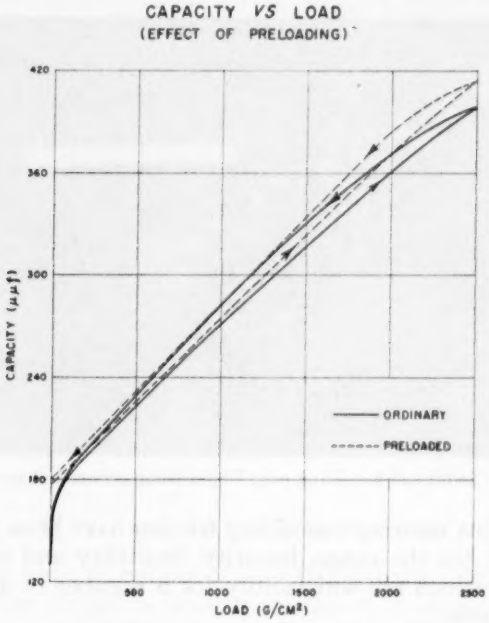

Fig. 3. Capacity *versus* load (effect of preloading).

D. Filpip Arrays

Thirty-six of these mica and steel condensers were made up into two blankets of 18 each on 1-in. centers in a 3 by 6 array. In the first of these blankets a plastic cover was heat-sealed in place and held the layers together. The second blanket used condensers with covers of spot-welded, 0.001-in. shim stock. Extensions of these metal covers were spot welded together making a single flexible framework with 18 sensitive areas. Figure 4 shows the parts and assembly of one of these Filpips.

E. Hysteresis Investigations

In an effort to reduce the error resulting from hysteresis, experiments were designed and conducted to see whether there was mechanical hysteresis in the mica, deformed metal sheets, plastic or metal covering or even the measuring equipment. The net result of these experiments pointed to a rubbing between the metal and mica. Therefore, graphite, oil, molybdenum disulfide powder and molybdenum disulfide in a lacquer base were tried as lubricants for the contact between the mica and the steel. There was no appreciable difference in the hysteresis with any of the lubricants used. Later experiments showed that a proper combination of lubricant and lubricated surface does reduce the hysteresis.

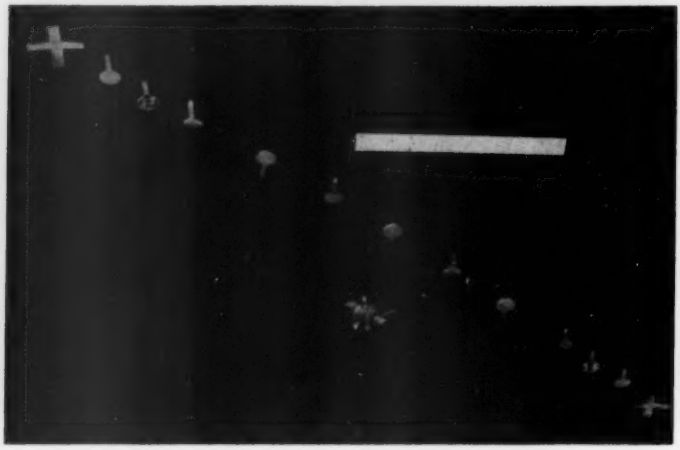

FIG. 4. Deformed metal and mica Filpip (components and assembly).

Other designs insuring less sliding friction have been tried but none yet developed has the range, linearity, flexibility and compactness of present units, which are satisfactory for a number of applications, in spite of hysteresis.

III. INSTRUMENTATION

The primary problem in this development is the measurement of capacity or, more accurately, capacity change. There are several ways in which this can be done: the capacitor can change the frequency of oscillation of an oscillator; the change in voltage across a resistor placed in series with the variable capacitor may be measured; or the variable capacitor may be made one arm of a bridge. This last method was selected and the bridge-type chosen had two resistance arms and two capacitance arms (Fig. 5). C_1 is a fixed capacitor, R_1 a variable resistor, R_2 a variable balancing resistance, R_3 a fixed resistance, and C_4 a pressure-sensitive capacitor and leads. The generator is connected between

points A and B and the dectector is connected between points C and D (ground). This is known as a grounded D-point series capacitance bridge.

Balance is obtained with no load on the capacitor by adjusting R_2 and R_1 alternately. R_2 adjusts for the magnitude of capacity C_4, and R_1 adjusts for any losses in C_4. Proper selection of bridge components results in substantially linear characteristics.

In designing the bridge, consideration had to be given to several points. It was necessary that one side of the pressure-sensitive capacitor be rounded to avoid changes in capacity when the capacitor was touched by the body, and it was desirable that one side of the detector be grounded to avoid pick-up. This was accomplished. The stray capacity between point A, the high side of pressure sensitive capacitor, and ground through the generator was reduced to a small, constant, balanced value by use of the bridge transformer. Another point con-

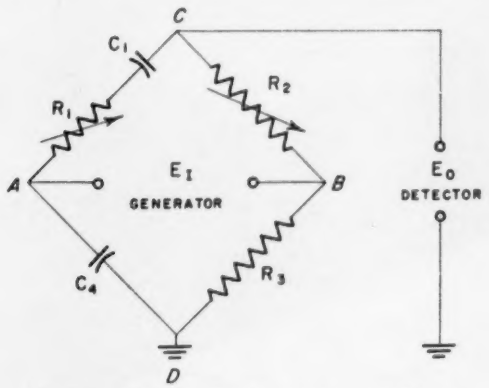

FIG. 5. Diagram of series capacitance bridge.

sidered was the large fractional change in capacity. In an equal-arm bridge the voltage output is linear with respect to change in one arm if that change is very small proportionally. This linearity can still be obtained with large proportional changes in one arm with an attendant decrease in sensitivity by making the bridge an unequal-arm bridge. The generator is connected to the bridge by means of a bridge transformer which is designed to give small balanced capacity to ground from each end of the secondary winding. This was found to be necessary in order to get a good clean balance of the bridge. The output of the bridge is shunted by a high Q parallel tuned filter. This filter shunts out 60-cycle pick-up and any harmonics which may be present in the oscillator.

In order to check the operation of all components together and to secure a unit which could operate directly from the 115-volt supply to

provide a signal for oscilloscope display or meter readings, several plug-in units were built. These are shown in Fig. 6. In one box is the Hartley oscillator, which uses a tube type 117N7 and operates at 3000 cps. and 10 volts. The next box contains the bridge transformer. Into it is plugged the bridge and the bridge output to the meter passes through the filter, mounted in the last box. A Filpip can be seen connected in the foreground. Small shielded cable is used between the Filpip and the bridge.

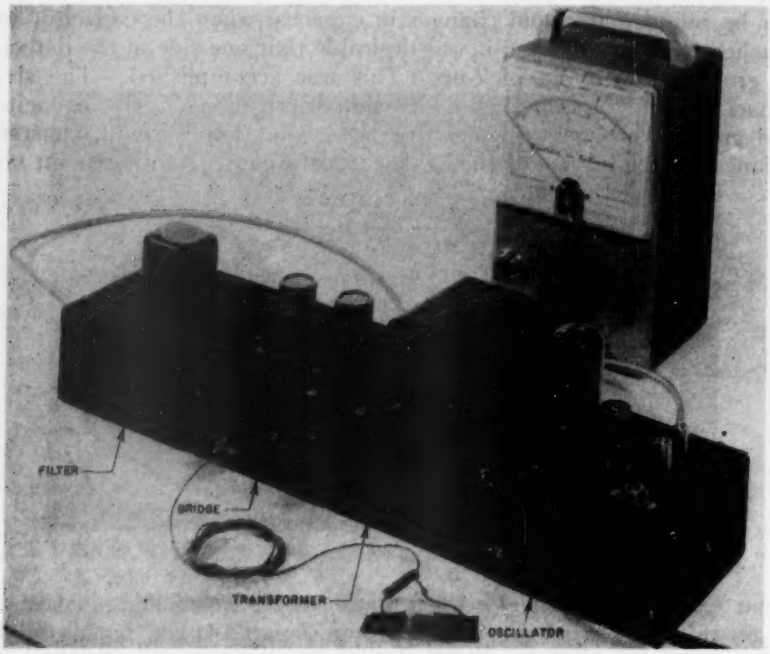

FIG. 6. Filpip plug-in oscillator-bridge and meter.

The next step was to build a single unit having all the necessary equipment needed to measure force with a Filpip. This had all the elements of the plug-in boxes plus a meter and meter amplifier and rectifier. In order to avoid the necessity of a low-voltage filament supply, another 117N7 was used as a linear amplifier feeding the meter through a rectifier bridge of four 1N48 crystal diodes. This unit is shown in Figs. 1 and 7.

In this development we have also kept in mind the fact that with many units in a blanket a fast scanning of the output of these units is desirable and, in some cases (dynamic measurements), even necessary. Each capacitor has been calibrated so that a single bridge can be used switching each sensitive unit in turn into the bridge. The output from

each contact of the switch is fed to a filter and a detector. The output may go to an oscilloscope with a horizontal sweep synchronized by an additional switch contact and long enough to give one sweep for each complete commutation In this way, using a long-persistence phosphor on the cathode-ray tube, one can observe a pattern consistng of a series of vertical bars each corresponding to a particular sensitive capacitor

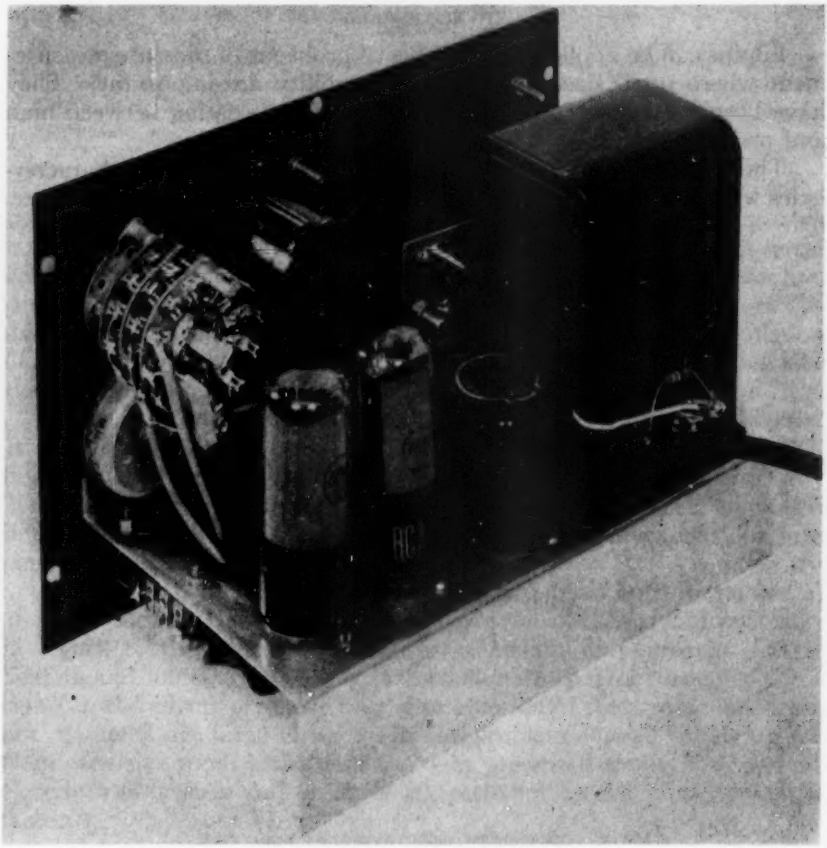

FIG. 7. Filpip electronic accessory assembly, without case.

with the height of each proportional to the output of the bridge. This arrangement has been tried using two different types of switches—one type motor driven, the other a relay-operated stepping switch. Both arrangements were fairly satisfactory. In each, however, there was a poor signal-to-noise ratio for small signals. This noise has not been investigated as yet. Two possibilities of its source are pick-up and contact bounce. However, in the stepping switch used, one set of contacts

were of the shorting type designed to eliminate pick-up during switching, and a few observations of the enlarged oscilloscope signal from the contacts showed no appreciable bounce.

It is, of course, possible to connect each pressure-sensitive capacitor to a separate meter and it may be feasible to use separate meters with a common bridge, connected to each circuit in turn by a switch.

IV. APPLICATIONS

Filpips can be applied to a number of problems of pressure measurement where small size, simplicity or flexibility are important. They have been used, for example, to measure forces existing between man and prosthetic devices, shoulder-borne loads, and seats.

The development is still underway and improvements in characteristics will permit even wider application of the principles described here.

EFFECTS OF SMOKES ON ATMOSPHERIC IONIZATION *

BY

ROBERT A. HESSEMER, JR.[1]

ABSTRACT

It is the purpose of this paper to report some of the initial results in the investigation of the effects of smokes on the emission of ions from hot filaments under atmospheric conditions; and to describe the special equipment developed for this purpose.

INTRODUCTION

Recently considerable interest has arisen in the behavior of the generation and utilization in atmospheric air of ions originating from hot filaments, and from radioactive materials. Of particular interest are the effects of air impurities, such as smokes, on the generation and control of ions. It is the purpose of this article to report some of the initial results in the investigation of the effects of smokes on the emission of ions from hot filaments under atmospheric conditions, and to describe the special equipment developed for this purpose.

As far as is known, this article and the work of Thomas L. Martin, Jr., while a student at Stanford University, represent the first detailed investigation of the effects of smokes on the (1)[2] emission of ions from hot filaments under atmospheric conditions. It is hoped that this information might form the foundation for future investigations into particular phases of the problem.

Information, such as presented in this article, is both fundamental and necessary for the complete solution of some of the existing problems in regard to the effects of smokes on filaments employed in electric heaters and ion sources. In regard to climate control through ionization (2), the effects of smoke on the production of thermionic ions from hot filaments are large indeed. In the problem of wall smudging (3) from excessive room ionization, the data presented show that open air electric wall heaters and ordinary cigarette smoke can be a very large factor.

ION EMISSION CHARACTERISTICS

Hot wires, such as platinum and Nichrome, when heated above 500° C. emit measurable quantities of both positive and negative ions. The exact nature by which these ions are emitted from the metal is not too well understood. This is due, for the most part, to the bewildering

* Condensed summary of a research program instituted by the Wesix Electric Heater Co. at Stanford University.

[1] Assistant Professor of Electrical Engineering, University of New Mexico, Albuquerque, New Mexico.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

array of variables that are encountered both in theory and in practice. Because of this, contradictions exist in the literature, and this leads to some confusion in regard to a true understanding of the exact phenomenon of emission.

In addition, some of these variables are extremely hard to detect, control, and account for. Most of these variables and accompanying difficulties stem from the action of the surrounding atmospheric air on the hot wire. The action of the air can be divided into two basic effects: (1) oxidation of the wire; and (2) action of air impurities such as smokes and fumes on ion production and movements thereafter.

Oxidation of the wire is an important factor since the oxide coating starts to form at temperatures considerably below the melting point of the metal. Moreover, in some cases, the oxide volatilizes at these temperatures. This causes the filament life-time to be very short. Thus, it is necessary to use a metal that is relatively free from oxidation, such as platinum, or a metal that quickly forms a relatively stable protective oxide coating, such as Nichrome.

In addition, evidence indicates that the oxide coating produces a sizable increase in the work function of the metal. This causes a reduction in emission in comparison to theoretical values for particle emission in a vacuum under conditions otherwise similar. Also, with the oxide coating, emission laws valid for clean metal surfaces must be re-examined before using. It turns out that certain parts of the ion emission data do, within experimental accuracies, obey some of the theoretical laws derived for particle emission from clean and pure metals in vacuum. However, these similarities do not prove the existence of an analogy that would associate the well known theories of particle emission in vacuum to the crude and conflicting theories of ion emission in atmospheric air. The oxide coating, with all its own variables, makes the likelihood of such an analogy appear quite small.

In spite of the complexity of the emission problem, certain basic facts seem quite well substantiated. All the known evidence relating to the formation of ions by hot metals quite conclusively shows that positive and negative ions are, in the majority of cases, the end products of two very separate and distinct phenomena. Of course, it is generally true that hot metals produce ions of both polarities simultaneously, but by suitably controlling some of the parameters, the ratio of the two ion currents can be made to change within very wide limits. This is true even at a constant temperature.

Positive ions originate from impurities in the metal filament (neglecting the ions of the filament material emitted only at temperatures above those used in this experiment) and are emitted as ions. Negative ions-though, are not emitted, but are formed by molecular capture, oxygen molecules in many cases, of electrons after the electrons have been

emitted from the filament. This capture, resulting in the formation of a negative ion, probably takes place in less than one microsecond at atmospheric pressures. This assumes, of course, that gases with a high electron affinity, such as oxygen, are in contact with the surface of the filament.

It is generally assumed that the electrons available for emission are the same as those available for electric current conduction. These so called "free electrons" move about within the conductor with velocities dependent upon the temperature. Their free paths are hundreds of atomic diameters, thus it is believed that the emitted electrons, for the most part, come from well below the surface. Such a hypothesis seems to eliminate, or at least diminish to small proportions, surface effects on electron emission such as the heat of surface charging. In addition, it also seems that the effects of the normal gaseous impurities in the air surrounding the wire would have little effect on the emission in terms of random "noise" fluxations. Experimentally, this was found to be true for negative ion currents where the space charge was no longer able to smooth out the randomness of emission. This is in marked contrast to the positive ion current which exhibited a large noise component. In fact, the noise component of the positive ion current was increased by any action that stirred up the slightest bit of dust in the room.

In a similar fashion, the negative ion current was not affected by small variations in the velocity of the air past the filament. In contrast, these same variations in air velocity produced noticeable changes in the positive ion current.

EXPERIMENTAL EQUIPMENT AND PROCEDURES

The investigation took on several aspects; however, only the results of the experimental work are reported in this article. For the experimental work, it was necessary to design and develop special equipment. In brief, the equipment consists of a hot filament with an upper and lower collecting plate. A variable direct voltage is placed across the plates with the filament kept at a voltage half way between. The smoke is produced and inserted into a duct, and then carried down the duct at a slow non-turbulent velocity. At the end of the duct, the smoke goes between the collector plates and then through a photoelectric unit that measures the amount of smoke (4).

The types of filaments tested were: nickel, Nichrome V, platinum, platinum-rhodium, Kanthal DS, and Chromel C. The selection of these filaments was influenced by the Wesix Electric Heater Co. of San Francisco, California. They had previously used several of the materials for filaments in electric heaters and in ion sources, and were desirous of obtaining data which would permit a critical evaluation of the suitability of these materials for use in commercial units.

The smokes used in this test were obtained from: bath wax,[3] tobacco,[4] and cigarettes. The selection of these smokes was governed by several factors: they are smokes of known composition; (5, 6) they are easily produced in controllable amounts; and they represent typical smokes encountered in places using electric heaters and ion sources.

The cigarette smoke was produced by smoking a cigarette in the conventional manner. In contrast, the tobacco and bath wax smokes were produced by heating the material in a small tin to the desired temperature. These smoke particle sizes are of the same magnitude as the wavelength of the light used to detect them. This makes it very difficult to measure the smoke in terms of number of particles; however, the smoke density can very easily be found in terms of percentage of light obstructed. This amount of obstruction is called smoke density on the graphs. Densities up to 20 per cent were obtainable from the smoke periodically exhaled in the normal course of smoking.

The experimental data were taken in a series of three tests: (I) ion current *vs.* operating time, (II) ion current *vs.* collector voltage *vs.* filament voltage, and (III) ion current and smoke density *vs.* operating time. Tests were for both positive and negative ions.

Since all the experimental work reported in this article was conducted under atmospheric conditions, the question very naturally arises as to the reliability of the results. Tests I and II were conducted specifically to show that ion currents from hot filaments under atmospheric conditions are relatively stable after about the first 100 minutes of operation. These stable values are reproducible not only from wire to wire but also over a period of time. Martin (2) has shown this to be true, and the author obtained enough data to arrive at the same conclusion. Thus, the experimental reliability of Tests I and II is well substantiated.

Test III was primarily an observation of the ion current changes when subjected to smokes. These changes are measured relative to initial uncontaminated values as determined in Tests I and II. In most cases, the changes are so pronounced and of such magnitude that it is quite apparent that they are produced by the smoke.

EXPERIMENTAL RESULTS

The purpose of Test I was actually three-fold: one, to find out just how the ion current varies with the life of the filament; two, to find out whether the current becomes stable, or relatively so, after a certain operating time has elapsed (if the current does become stable after a certain time, then this stable point can be used as a point of reference for other measurements, since the effects of smokes are measured relative to such a reference point); and three, to determine whether the current exhibited changes when interrupted by intervals of off periods.

[3] A commercial form of wax used principally in chemical laboratories.

[4] Tobacco from unraveled cigarettes.

It was found that a new wire on first heating emitted large quantities of ions. In the next 60 minutes of operation the rate of emission went through various and sometimes sporadic changes. However, after about 100 minutes, the current became relatively stable. It was also found that the current did not exhibit any steady-state change when interrupted by intervals of off periods.

Test II was conducted on wires that were pre-aged about 100 minutes. The purpose of this test was to obtain ion current, collector voltage, and filament voltage characteristics at the stable point. This information then serves as a control in that the effects of smokes are measured relative to these values.

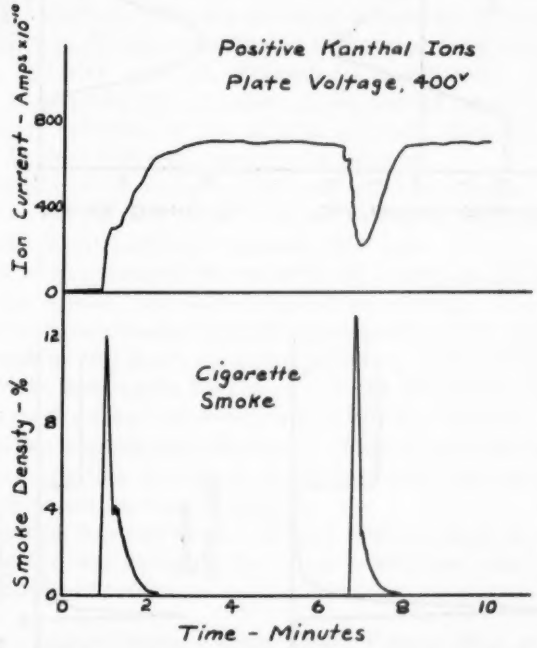

FIG. 1. Effect of cigarette smoke on positive ions from a Kanthal filament.

The purpose of Test III was to observe the variation in ion current when the smoke density was increased from zero up to a maximum value and then decreased down to zero. The wires were pre-aged at least 100 minutes so that the ion current when uncontaminated with smoke was relatively stable with time.

Preliminary tests indicated that these data would be extremely difficult to record manually point by point. Thus, both the ion current and smoke density were recorded simultaneously on separate Esterline-Angus recorders. Much of the information contained in these graphs

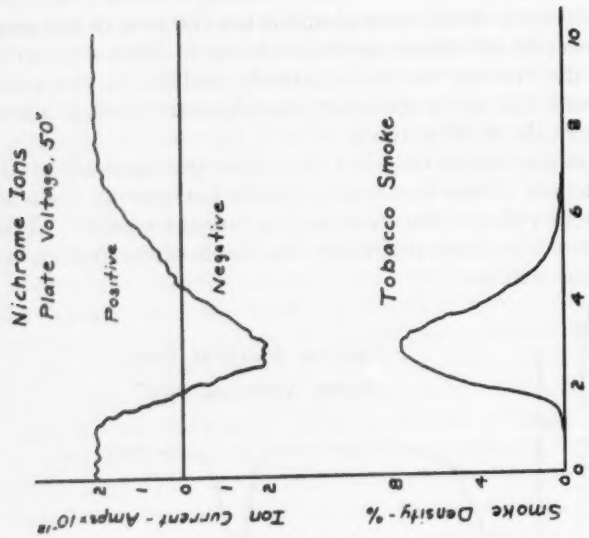

FIG. 3. Effect of tobacco smoke on ions from a Nichrome filament.

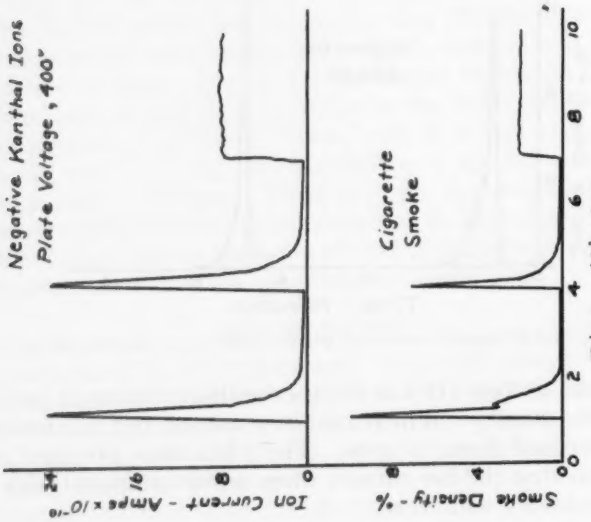

FIG. 2. Effect of cigarette smoke on negative ions from a Kanthal filament.

is quite complex, and therefore difficult to transform adequately and accurately into words. Figures 1, 2 and 3 show the effects of smoke for several specific cases.

The general action of puffs of cigarette smoke transported past the hot filament at several-minute intervals was to increase the amount of ion current flowing to the collector plates. For positive ions, the increase often remained for ten minutes or more after the main body of the puff of cigarette smoke was transported past the filament. This is in contrast to the negative ion-current increases which subsided to their quiescent value in several minutes.

The action of the cigarette smoke on negative ions emitted from Nichrome and Chromel filaments deviated somewhat from this general pattern, as follows: the cigarette smoke initially caused the ion current to reverse in polarity with an increase in magnitude. This change lasted for a few seconds (the duration of the puff of smoke) after which time the current returned to its original polarity with an increase in magnitude. It then followed the general pattern.

The magnitude of the current increases was quite large. For example, the positive ion current from Chromel increased 200 fold, and negative ion current from Kanthal increased 1600 fold.

The action of the tobacco smoke was not nearly as uniform as that of the cigarette smoke, nor was it nearly as strong. The method of generating the tobacco smoke allowed its quantity at the filament to be varied from zero at the start, up to a maximum value after 4 minutes, and then down to zero again by the end of the 10-minute test. In all cases the observed change occurred only while the tobacco smoke was at the filament in measurable amounts. This is certainly in contrast to the changes caused by the cigarette smoke which were apparent long after the cigarette smoke was detectable.

In addition, the tobacco smoke did not always result in an increase or decrease in the ion current; for some conditions the ion current remained unchanged.

TABLE I.—*Space Charge Current Changes (Plate Voltage, 20 to 50 Volts).*

	Cigarette Smoke		Tobacco Smoke		Bath Wax Smoke	
Filament	Positive	Negative	Positive	Negative	Positive	Negative
Platinum	7	5	0.8	0.7	0.8	0.7
Platinum-Rhodium	3	5	0.9	0.7	0.6	0.6
Nickel	7	7	0.5	1.3	0.8	1.0
Nichrome	9	±10	1.8	−1.0	0.6	−1.0
Chromel	4	±30	0.8	0.5	0.6	−1.0
Kanthal	1.2	—	0.5	—	0.5	—

NOTES: 1. Change = $\frac{\text{changed value}}{\text{initial value}}$

2. Minus sign indicates a change in current polarity

3. Plus-minus sign indicates peaks of both polarities occurred.

TABLE II.—*Saturation Current Changes* (*Plate Voltage, 400 Volts*)

Filament	Cigarette Smoke		Tobacco Smoke		Bath Wax Smoke	
	Positive	Negative	Positive	Negative	Positive	Negative
Platinum	15	24	1	1.3	1	1.4
Platinum-Rhodium	15	8	1	1.4	1	1.5
Nickel	60	20	0.5	2.6	1	1.0
Nichrome	150	± 8	17	0.2	4	1.0
Chromel	200	± 12	7	1.5	2	1.5
Kanthal	120	1600	5	±15.0	2	±10.0

NOTES: 1. Change = $\frac{\text{changed value}}{\text{initial value}}$

2. Plus-minus sign indicates peaks of both polarities occurred.

With but few exceptions, the action of the bath wax smoke was similar so that of tobacco smoke.

A complete tabulation of these changes in terms of peak increases or decreases in relationship to the initial undisturbed values is given in Tables I and II.

EFFECTS OF GASES ON EMISSION CHARACTERISTICS

The extreme sensitivity of the magnitude of ion emission to small concentrations of surrounding gases seems to have gone unnoticed until very recently. This phenomenon is believed to be a surface action. In the simplest case, this might be merely a dissociation of the gas molecules at the hot surface and subsequent flow of the ions thus formed. It seems more likely, though, that the phenomenon is more complex than this. Certainly such actions as van der Waals forces, chemisorption, electron affinity, and oxide characteristics cannot be completely accounted for by dissociation. To date, all of these various actions have not been integrated to form a theory consistent with all the evidence.

Along with this lack of theoretical understanding is an almost equal lack of experimental evidence. It was not until 1944 that Rice (10) noted gases containing halogens increased the positive ion emission from a platinum filament by many fold. The sensitivity of one such filament was such that only a few parts of freon, a dichlorodifluoromethane, per ten thousand of air increased the positive ion emission several fold. A much larger concentration increased the emission as much as one thousand fold. In addition, the emission from the platinum filament was found to be increased by the following: carbon tetrachloride, chloroform, and solid particles of the iodides, chlorides, bromides, and fluorides.

The extreme sensitivity of the positive ion emission from platinum has been utilized to develop a very sensitive leak detector (10). White (1) suggests that the strong electron affinity exhibited by the halogens might play a role.

The effects of the various smokes on the filaments under the various conditions seem quite complex, indeed. However, the effects of the

cigarette smoke seem similar to the effects of halogen gases on positive ion currents. The obvious conclusion is that cigarette smoke contains some halogen compound. This has been suggested in the literature (10). A careful survey, though, of the chemical analyses conducted on cigarette smoke does not support this suggestion. Table III is a compilation and summary of some of these chemical analyses. None reports any halogen compounds whatsoever. This lack of halogen compounds in cigarette smoke has been further substantiated by work done at Stanford Research Institute. Table IV gives the composition of tobacco.

TABLE III.—*Composition of Cigarette Smoke.*

Component		Reference
CO_2, ml/cig	34*	11***
C_2H_2, ml/cig	0.05	
H_2S, vol. %	0.0019*	
HCN, vol. %	None*	
CO, vol. %	0.98	
Other hydrocarbons	undet'n	
True NH_3, % mg/l	0.24**	12
NH_3 and simple amines, mg/l	0.35	
Acetic Acid, mg/l	6.47	
Formic Acid, mg/l	0.95	
HCN, vol. %	0.020–0.034	13
Pyrrole, mg %	20–80	
True NH_3, mg/l	0.7	14
Nicotine, mg/l	7.1	

NOTE: Each reference was looking principally for only those components listed. Therefore, not all components were analyzed for, in all the references.

* The reference gives varying values by other observers.

** Tobacco type: blend of Turkish, Bright and Burley tobacco.

*** Principal smoke, normal smoking conditions, smoke stream acidic, observation conditions 745 mm. 25° C.

TABLE IV.—*Composition of Tobacco** (5).

Percentage by Weight					Volume
Total Nitrogen	Protein Nitrogen	Amino Nitrogen	Nicotine	Starch	Nonvol. Acids, ml 0.1 N alkali
1.80	0.70	0.17	1.75	3.50	14.00

* An average composition of some organic constituents of a blend tobacco. Data are not available to show composition of smoke obtained by heating the tobacco. However, these data do show that the tobacco is composed largely of sugars, organic acids, and nitrogenous materials. No halogens were initially found in the tobacco and thus it may be concluded that no halogens would be found in the smoke.

It seems fair to conclude that what actually happens when there are variations of ion emission from hot filaments in air contaminated with gases is certainly not well established. In fact, there is no generally accepted explanation for a number of the characteristics that have been observed both by others and by this author. However, certain facts seem quite well established.

ANALYSIS OF DATA

An analysis of the experimental data shows that the ion-current changes are due to two causes: (1) surface reaction between the smoke and the filament; and (2) strong space-charge forces originating from the large smoke ions.

The effects of surface reaction on emission characteristics are indeed complex phenomena and could well be the subject for a future investigation. However, the author's work establishes the following facts:

It is known that smoke particles tend to be repelled by hot bodies. This results in the filament being surrounded by a ring (7) approximately 0.03 cm. thick that is quite free from particulate matter. The existence of this ring suggests that only those constituents of the smoke of molecular size are able to penetrate to the filament surface to produce a reaction. In this respect, the effects of smokes are actually the effects of gases in the smokes.

It is also known that most of the smoke particles produced are uncharged, particularly if the smoke concentration is high (8). However, smoke particles become charged quite readily when mixed with large quantities of small ions. In comparison with the small ions, the smoke particles are very immobile and form a relatively fixed charge distribution in space.

It can be shown (9) that the existence of such a space charge accounts for many of the effects of smokes on ion current characteristics. These effects are particularly noticeable at low plate voltages.

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Step Function Potentiometer for Torque Amplification Devices.—A step-function potentiometer whose response is extremely sensitive is now available for the first time for use in torque amplification devices. Designed and manufactured by Computer Instruments Company, Brooklyn, N. Y., it is known as the Model 108. It is already being used in military equipment in angle of attack indicators, pressure transducers and gyro torquing devices for aircraft, guided missiles and navigation systems.

The entire voltage output of the Model 108 is obtained over a shaft rotation of only three degrees. The voltage sensitivity is more than one hundred times that of the conventional one-turn potentiometer. It is therefore the first highly sensitive potentiometer adaptable to transducer applications involving extremely small angular motions.

For such transducer applications, relay and switch types of controls have formerly been used. Because of their nature there is always a lag between input and output, so that response is hard to control and dead space must be large to offset continuous oscillations. With the Model 108, however, the input to the clutch or motor coils is directly proportional to the relative displacement of input and output shafts, so that the response is immediate and, with oscillations minimized, the dead space is zero.

For torque amplification, the case of the Model 108 can be made to keep pace with the potentiometer, so that its functioning is practically unlimited. The case, containing the resistance element, is driven by a motor whose shaft is double-ended. A torque of as little as 0.1 in.-oz. will make the potentiometer shaft rotate, and the resulting electrical signal will cause the motor shaft to rotate. This drives the potentiometer case directly (or through a suitable gear reduction) in such a direction as to reduce the potentiometer output signal and develop the stall torque of the motor, which typically ranges from 2 to 4 in.-oz. The torque amplification is thus between 20:1 and 40:1.

The extreme sensitivity of the Model 108 is due to the use of a specially shaped carbon-film element of virtually infinite resolution. The Model 108 is equipped with ball bearings and a flange-type mounting. As Model 108J, the potentiometer is also available with a sleeve bearing and alternate bushing or flange-type mounting.

Television Eye Is Firewatcher.—A new TV microwave link relays pictures taken from the top of a fire lookout tower deep in the forest, to a central headquarters more than 50 miles away, thus enabling forestry officials to watch for fires and lawbreakers while remaining at their forest headquarters. In this application of the microwave link, the camera is mounted in a special dome atop a fire control tower, rotated through a complete circle once every two minutes, while its telephoto lens scans the surrounding countryside. The picture is relayed to forest headquarters where the observer sees it on a television monitor. While rotating, degree readings are given which enable the forestry officials to locate a fire.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS*

A CATHODE EMISSION TRACER

A cathode emission tracer developed by L. A. Marzetta of the National Bureau of Standards provides a rapid, convenient method for measuring and evaluating the performance of thermionic cathodes. The new instrument automatically produces a calibrated plot of the emission characteristics of the cathode of a diode on the screen of a cathode-ray oscilloscope. A "$\frac{2}{3}$-power network" is incorporated into the system and may be used at the option of the operator for linearizing the plot. Negligible heat is contributed to the diode under test since the tube is subjected to only a 10- or 100-microsecond pulse at rates of either 5 or 30 cps. Provision is made for instantaneous plate currents as high as 10 amperes or for plate voltages up to 5000 volts, although these limiting values are not available simultaneously.

Past methods of obtaining emission data have usually been based on two alternative procedures. In one system, a continuous current is applied to the test diode at selected amplitudes. This system has the disadvantage of requiring a water-cooled anode because of the large steady-state power dissipation. In the second method, current is applied intermittently in short rectangular pulses. Unless operated at a low duty cycle, however, the rectangular pulse system contributes heating to the diode which interferes with planned aging of the tube. Moreover, the abrupt rise in current may produce a sparking effect and anomalous current density readings. In both the continuous-current and intermittent-current methods, emission curves are obtained by manually varying the tube current and voltage and then plotting the values on $\frac{2}{3}$-power graph paper to linearize the portion of the characteristic curve that is governed by the Langmuir-Childs law.

The instrument developed by the Bureau scans the tube characteristic curve with a brief saw-tooth voltage wave applied to the diode at a low repetition rate. At the discretion of the operator, the saw-tooth voltage wave can be either 10 or 100 microseconds long, and the repetition rate can be either 5 or 30 cps. "Single-shot" operation is available as well. Since the duty factor is low, the diode need dissipate only the negligible amount of heat that is contributed by emission current. Furthermore, the gradual voltage rise eliminates most of the sparking.

Two parallel-connected power triodes (type 304TH's) are connected in series with the test diode. The high transconductance of this type

* Communicated by the Director.

of tube permits large changes of plate current for moderate grid swings below zero bias. The grids of the control triodes are raised from cutoff to zero bias with a saw-tooth signal, resulting in a sawtooth pulse through the test diode. This signal is also applied to the horizontal amplifier of the oscilloscope, and the voltage across the tube appears on the vertical amplifier. The composition of the signals produces the desired emission characteristic.

The saw-tooth voltage originates in a repetitive multivibrator or a single-shot multivibrator, depending on the time duration and rate desired. The output of the multivibrator is applied to a condenser-charging circuit and generates the saw-tooth wave which is amplified to a level that is sufficient to raise the grids of the 304TH's from cutoff to zero bias. A type-6V6 tube satisfies the driving requirements, since the grids are not driven into the positive grid current region.

The instrument also provides a round-dot calibrate marker whose position can be manually controlled. The current and voltage signals from the test diode to the oscilloscope alternate with rectangular calibration pulses. The amplitudes of these pulses are manually controlled and together produce a round-dot calibration marker on the screen. Two meters on the instrument panel monitor the vertical and horizontal positions of the marker and indicate the diode voltage and current at any point on the trace representing the tube characteristic.

Another convenient feature of the NBS cathode emission tracer is a special network capable of linearizing a tube characteristic in which the plate current varies as the three-halves power of the plate voltage. Excursion from the linearized function because of current saturation becomes more evident when this feature is used, and it eliminates the manual plotting of points on 2/3-power graph paper. The special network uses a series of germanium diodes, each biased to a different voltage level. As the instantaneous input voltage increases, successively more diodes become conductive. The linearizing action is achieved through the resulting variation in impedance.

For further technical details, see "A High Power Pulser Aids Cathode Studies," by L. A. Marzetta (NBS), *Electronics*, Vol. **27**, No. 3, p. 178 (March 1954).

A TIME-PROPORTIONAL ELECTRONIC THERMOSTAT

A versatile electronic thermostat is now in use at the National Bureau of Standards as a general-purpose temperature controller for a variety of applications. Developed by F. A. Ransom of the NBS electronic instrumentation laboratory, the instrument is designed for flexibility, high sensitivity, and provides precision temperature control over a wide range of temperature and power requirements.[1]

The device features such advantages as (1) no appreciable dead

[1] "A Time-Proportional Electronic Thermostat," by F. A. Ransom, *Control Engineering* (McGraw-Hill Publishing Co., 330 W. 42nd St., New York 36, N. Y.) Vol. **1**, p. 1 (Jan. 1954).

zone; (2) the sensitivity may be raised very high without objectionable loss of stability, reducing the deviation from the control point to a minimum with any load changes; (3) capability of handling power requirements ranging from milliwatts to kilowatts for control; (4) the use of sensing elements which may be a resistance thermometer or a thermistor connected in a bridge circuit, or a thermocouple connected to a chopper circuit; and (5) the use of standard commercial components. The thermostat utilizes a principle originally described by M. Gouy;[2] the power supplied to the heating element is switched on and off in a regular cycle, but the fraction of the cycle during which the power remains on is proportional to the deviation from the desired temperature.

The temperature sensing element—usually a resistance thermometer or thermistor—is connected in one arm of an alternating-current bridge. The adjacent arm of the bridge is a variable resistor adjustable to the desired temperature control point. A 164-cps. oscillator energizes the bridge and also supplies synchronizing voltage to a twin-diode synchronous detector. When the actual temperature at the sensing element deviates from the control temperature, the resulting bridge error signal is amplified and applied to the center leg of the synchronous detector. The resulting current in the center leg is determined by the amplitude and phase of the error voltage, being zero when the error voltage is zero.

Also applied to the detector, in series with the error voltage, is a voltage from a sawtooth oscillator. The result is that the output of the detector consists of a sawtooth voltage that operates about a reference level which varies with the error voltage. This detector output is applied to a Schmitt trigger circuit, which in turn actuates a relay that switches the power applied to the control heater.

With this arrangement the sawtooth voltage applied to the detector can be adjusted so that, when the temperature deviation and thus the error voltage are zero, the control relay applies power to the heater 50 per cent of the time. Any temperature deviation from the control point then alters the proportion of the "duty cycle" during which power is applied to the heater; this proportion varies above or below 50 per cent depending on the magnitude and direction of the temperature deviation. Large temperature deviations, beyond the proportional control range for which the instrument is set, result in the heater power being either on or off continuously—depending on the direction of the deviation—until the temperature is again brought within the proportional range. The duty cycle, determined by the frequency of the sawtooth oscillator, is designed to be adjustable over a range of about 5 to 15 seconds to meet the needs of any particular controlled process.

Since the controller is of the time-proportioning type, its time of

[2] *Journal de Physique* (3rd Series) Vol. 6, pp. 479–483 (1897); *J. Am. Chem. Soc.*, Vol. 42, pp. 60–68 (1920).

response to a temperature change is slightly longer than that of other types of controllers. Also, if the total power is switched in the control of processes having small thermal capacities and short thermal time lags, the temperature may cycle about the control point. In such cases the magnitude of the cycling can easily be minimized supplying a portion of the required power continuously and switching only the power needed to compensate for any load changes in the controlled process.

This thermostat has been used successfully to control a number of processes at NBS, and experience shows that its sensitivity, stability, and flexibility make it valuable for many laboratory applications requiring precision temperature regulation. In a typical NBS application the thermostat has for many months held standard electric cells, immersed in an oil bath, to a controlled temperature of 28° C. within ± 0.001° C.

Another use of the instrument has been in a small electrical furnace. The typical small heated-air oven is ordinarily difficult to control because of its low thermal inertia. Using the NBS thermostat, the temperature was maintained to within ±0.1° C. over a range from 250° to 450° C.

NOTE: For other work on this general type of time-proportioning thermostat, see U. S. Patent No. 2,376,488, Jones, May 1945.

THE FRANKLIN INSTITUTE

ANNUAL REPORT OF THE BOARD OF MANAGERS FOR THE YEAR 1953

The Annual Report of the Board of Managers for the year 1953 is presented to the membership by the President on behalf of the Board.

OFFICERS AND BOARD OF MANAGERS

S. Wyman Rolph was re-elected President for the second year at the annual Organization Meeting of the Board of Managers. Other officers elected for 1953 were: Executive Vice-President—Henry B. Allen; Vice-Presidents—Richard W. Lloyd, G. H. Clamer, James H. Robins, and Morton Gibbons-Neff; Secretary—Henry B. Allen; Treasurer—Hamilton V. Bail; Assistant Secretaries—Hamilton V. Bail and John Frazer; Assistant Treasurer—Cecil M. Waterbury. In June Mr. Waterbury was also elected an Assistant Secretary.

On April 15th the Board of Managers regretfully accepted the resignation of George Wharton Pepper from active membership on the Board; and in view of his many years of valuable service, he was elected an Honorary Member of the Board of Managers.

Recorded with deep regret was the death on December 4th of Marshall S. Morgan, who had served as a member of the Board since 1914.

On October 21st, W. Maxwell Scott, Jr. and John S. Malick were elected to fill two vacancies on the Board of Managers.

MEETINGS

Attendance averaged 304 at the eighteen stated meetings and meetings held jointly with various technical societies. The average attendance at the dinners preceding these meetings was 176.

In May, Benjamin F. Fairless gave the Edward G. Budd Lecture and at the same time received the Vermilye Medal, awarded to him by The Franklin Institute for his outstanding achievements in the field of Industrial Management.

The James Mapes Dodge Lectures, usually given during Christmas Week, were postponed this season until January of 1954, to allow more people to attend.

Our meeting rooms were used 434 times in 1953, including our own activities. This represents an increase over last year's total of 407. The availability of our facilities for scientific, technical and educational purposes is one of the ways in which the Institute serves the community.

LIBRARY

Acquisitions during the year totalled 5261. Of these, 534 volumes, 695 pamphlets, and 1291 maps were received as gifts; 1183 volumes were purchased; and 1558 volumes were added by binding.

The gifts were received from members and friends of the Institute, other libraries, and industrial companies. One particularly noteworthy volume received as a gift from Boies Penrose was a first edition (1482) of Euclid's *Praeclarissimus Liber Elementorum Euclidis Perspicacissimi*. The United States Government presented a collection of bound volumes of *Daily Weather Maps*, 1871 to date; *Monthly Weather Review*, 1875 to date; and a set of *Climatological Data* from every state, 1890 to date.

Publications and proceedings of institutions all over the world were received in exchange for our own JOURNAL.

Patent specifications have been received to date, are completely bound, and have been in great demand throughout the year.

The Library was visited and consulted by members, and by research personnel from both

the Institute and industrial companies. Requests for photostats from the Library collection continued, and 11,829 photostats were furnished.

The Library Committee has continued to make additions to the Library in order to give every possible assistance for research in science and technology.

On January 1, 1954, the Library contained 146,275 volumes, 51,739 pamphlets, and 9359 maps.

JOURNAL OF THE FRANKLIN INSTITUTE

The December 1953 issue of the JOURNAL OF THE FRANKLIN INSTITUTE was dedicated to the Aviation Industry on the Fiftieth Anniversary of the Wright Brothers' first flight at Kitty Hawk. Grover Loening, who has been active in aviation almost since its beginning, prepared an authoritative survey paper—"Fifty Years of Flying Progress"—which not only covered past achievements but delineated some of the pressing aeronautical problems which are still to be solved.

The first monograph under the auspices of the JOURNAL was published in July. Written by Alfred J. Büchi, Monograph No. 1 gives a detailed account of the history and development of exhaust turbocharging of internal combustion engines. It has had a wide circulation both in this country and abroad.

Over the past five years, circulation (based on December mailings) has increased 5 per cent, from 4356 in 1950 to 4702 in 1953. The JOURNAL goes to 43 foreign countries as well as to all 48 states in our own country.

In 1953, 64 papers were submitted for consideration. Of these, 21 were published, and 21 were added to the list awaiting publication. Although the JOURNAL appeared with a new cover—white coated stock—the quality of the research papers remained unchanged, maintaining the high standards set in previous years.

MUSEUM AND PLANETARIUM

The increase in the number of visitors reported for 1952 was continued during the year under review. Comparative figures are:

	Paid	*Free*	*Total*
1952.....	205,302	79,848	285,150
1953.....	204,704	84,698	289,402

Exhibits

The year was marked by several noteworthy new exhibits in the Museum, the most conspicuous of which were:

"Oil Serves America"—a comprehensive and dramatic survey of the part played by the petroleum industry, sponsored by the Sun Oil Company.

"Man's Versatile Servants"—a spectacular display illustrating the history and applications of the platinum group of metals, sponsored by the International Nickel Company.

"The Forming and Welding of Steel"—an exhibit demonstrating steel welding, sponsored by the Budd Company.

"Fiftieth Anniversary of Powered Flight"—enabling us to put on public display for the first time a selection from the original records and instruments bequeathed to the Institute by Orville Wright.

An exhibition of material furnished by the Navy Aviation Supply Office, embracing a cut-away airplane engine, instruments, and survival equipment.

"Power for Peace"—a large display of photographs arranged by the Department of Defense to illustrate life in the Armed Forces.

"Light Through the Ages"—a new arrangement of interior lighting devices completed from the material given to the Museum by the late James D. Lee, Jr.

To supplement the standard features of the Museum, a series of diversified but balanced temporary exhibits and demonstrations was arranged as in former years. These included the popular "House of Magic" by arrangement with the General Electric Company, and the

Industrial Arts Exhibition for the promotion of arts and crafts in the schools, sponsored by the Ford Motor Company.

The special demonstrations conducted by the Museum staff of demonstrators have continued to attract good attendance.

The annual Science Fair, conducted in cooperation with *The Philadelphia Inquirer*, attracted more exhibits than before from students in local schools who are interested in science studies.

Gifts and Loans

Demands upon the available exhibition space make necessary a strict supervision over gifts and loans offered to the Museum, but some additions have been gratefully accepted. Among these were:

A lightning rod exhibit, given by the Home Insurance Company of New York.

Surveying and map instruments, given by Major J. B. McNair, Los Angeles, California.

A surveyor's compass made by Benjamin Rittenhouse and an enlarged working model of a Swiss watch presented to John Wanamaker, given by Mr. and Mrs. V. F. Emerson, Villanova, Pennsylvania.

A water color drawing of the *U.S.S. Saratoga*, training ship of the Pennsylvania Naval Reserve, given by Captain H. D. Glenn, Wilmington, Delaware.

A writing desk purchased by Benjamin Franklin in France and brought by him to this country and 18 commemorative china plates, lent by the Misses Margaret and Emily Bache, Philadelphia, Pennsylvania.

A wooden bust of Benjamin Franklin, signed by J. Maene, given by Mr. W. Hardt, Philadelphia, Pennsylvania.

Phonograph and radio console, with records, lent by the Radio Corporation of America, Camden, New Jersey.

Special Activities

The customary program of lectures in the Fels Planetarium was supplemented by special lecture-demonstrations for Cub Scouts (of whom 2210 attended) and for students observing the celebration of Latin Week in connection with the Classical Society. The 20th anniversary of the opening of the Planetarium was celebrated with appropriate ceremonies on November 6th. An entirely new Christmas demonstration was strongly supported by the Philadelphia Council of Churches, with the result that the attendance during the month of December exceeded that of any other month in the history of the Planetarium except for the two opening months.

The Science Adventures series continued to attract many young people during the summer vacation period; and the Winter Workshop classes in Photography, Radio, Modelmaking, Basic Chemistry, and Astronomy and Meteorology were attended to maximum capacity. An anonymous benefactor generously contributed funds for "scholarships" as well as for books and much needed tools for the Workshop.

An in-service course for teachers in the Philadelphia Public Schools was conducted by members of the staff and was well attended.

Fire Prevention Week was marked by a spectacular display of fire-fighting methods staged by the City's fire companies and by a series of appropriate lecture-demonstrations for students of local schools.

COMMITTEE ON SCIENCE AND THE ARTS

The Committee on Science and the Arts met nine times, and 31 subcommittee meetings were held. At the annual Medal Day exercises on October 21, eleven medals were awarded, as follows: Cresson Medals to William Blum, George Russell Harrison, and William Frederick Meggers; a Longstreth Medal to Chester F. Carlson; a Levy Medal to George Cheney Newton, Jr.; a Henderson Medal to Adolph Meyer; Wetherill Medals to Robert H. Dalton and S. Donald Stookey; a Clamer Medal to Robert Franklin Mehl; a Ballantine Medal to David G. C. Luck; and the Franklin Medal to William Francis Gibbs. Owing to the absence of Frank Lloyd

Wright, candidate for the Brown Medal, conferment of this award was postponed. A George A. Hoadley Certificate, for 25 years of service on the Committee, was presented to Colonel H. B. Ely.

RESEARCH LABORATORIES

The Bartol Research Foundation (Swarthmore, Pennsylvania)

For the time being the Bartol Research Foundation is stabilized in its research plan which, among other things, covers nuclear physics, using the two Van de Graaff generators and the Cockroft and Walton set, and certain aspects of artificial radioactivity. In this latter field recent experiments of a very interesting nature have been conducted concerning inner bremsstrahlung and resonance fluorescence of nuclei.

Problems having to do with the solid state, with special relation to the electrical properties of compounds at high temperatures and to secondary emission of electrons from metals, have continued to engage our attention. In the latter investigations the small linear accelerator has continued to function very satisfactorily. Researches on light emission from phosphors have been continued.

The research output of the laboratory has continued at a high level, as represented by the presentation of twelve papers at the recent meeting of the American Physical Society in New York and eight papers to be presented at the forthcoming meeting of that Society in Washington, D. C.

The cosmic ray researches carried out in India and in South America have been completed and have resulted in valuable additions to our knowledge in the fields concerned.

Certain elaborate instruments for research in nuclear physics and radioactivity, to be used in conjunction with the generators, have been completed in our shop or are in process of completion. Several very modern electronic devices have been obtained at no little cost for advancing the methods of nuclear particle detection employed in the laboratory.

The Biochemical Research Foundation (Newark, Delaware)

The Biochemical Research Foundation has had a year of hard work. After our good run of discovery in regard to 2-desoxy ribose nucleic acid (2DG) and establishment of its value in the inhibition of glycolysis in cancer, we were left with the elaborate study of its application and effects. After every important development there always remains a clearing-up of many details; and these involve hard work and plugging, during which time it is easy for the experimentalists to feel a let-down. Fortunately, we have avoided this let-down, and this has been due to the quality of our staff, although we have not yet been able to get the quality of assistance they require owing to the conditions of the times.

Each analysis of 2DG required a lot of work. Chromatographic methods were a great help. The proper dose and method of application required extensive experimentation.

One difficulty was to get 2DG to penetrate to the tumor as chromatographic analysis showed that little was found in the tissues. We had enough evidence to show that if 2DG was brought into proximity to the tumor cells, it would be effective in stopping the tumor cell growth.

We have studied a considerable number of other substances in regard to their effect on mitosis of cells and inhibition of glycolysis with the hope of finding a new substance which would act as an adjuvant and carrier with 2DG. These were reported in the December 1953 issue of the JOURNAL OF THE FRANKLIN INSTITUTE.

The result of our year of plugging has cleared the slate, and the coming year promises to be one of more bold experimentation with the promise of rewarding facts.

The tissue culture department has been active not only with the testing of various materials, but in the improvement of its own technics. Particularly useful has this department been to the study of the effects of ultraviolet light on the killing of cells.

The chemists have had to synthesize a number of new products, and we are still unsatisfied with the yield in the synthesis of 2DG. The purification is also difficult.

The electrophoretic department is still concerned with the purification of enzyme, particularly phosphatase, and also with the study of certain clinical conditions by means of electrophoresis.

There is an active study of age and aging processes, particularly in relation to enzyme; and this holds promise.

The Library continued its activities, and many new reprints have been added to our collection. The price of books, of which there are many new ones, doubled along with many other costs.

The Biochemical Research Foundation looks forward to a good future based on the spade work it has done this year.

The Franklin Institute Laboratories for Research and Development (Philadelphia, Pennsylvania)

The Franklin Institute was conceived in the early years of the nineteenth century to promote the physical and engineering sciences. For more than 129 years it has served the community and the nation in fulfilling its purpose. The sustained growth of its laboratories in the last decade has placed the Institute in a position to be of service to industry, the government, and to the general public. In this period a large part of our effort was devoted to national defense. However, the year ending December 31, 1953, showed a marked increase in activity for private industry. There was an over-all increase in income of 13 per cent over 1952. The following statement, in approximate figures, illustrates this growth:

	1951	*1952*	*1953*
Revenue from Industrial Projects	$ 212,000	$ 252,000	$ 460,000
Revenue from Government Projects	1,909,000	2,326,000	2,401,000
Total Revenue	$2,121,000	$2,588,000	$2,861,000

During 1953 we received 92 contracts, of which 59 were for industry and 33 were for various departments of the government. Of our industry-supported research, 85 per cent comes from five major industries: namely, (1) Primary Metals, (2) Electrical Machinery and Equipment, (3) Petroleum and Coal Products, (4) Paper and Allied Products, and (5) Chemical and Allied Products. Work sponsored by trade associations has continued to increase. This is a most important activity in industry-supported projects and will be pushed actively in 1954.

Thirty-eight major projects were completed in 1953, 17 for various government agencies and 21 for industrial sponsors. A high percentage of completed projects resulted in new work for the same company, indicating complete satisfaction with the work done for the sponsor. Following is a review of some of the completed contracts:

National Defense: A new gun for the Army was completely designed at our Laboratories and tested at Aberdeen Proving Ground. Comments on its performance are highly favorable.

Electrical Machinery Industry: A sponsor in this industry assigned us the task of designing a water-lubricated thrust bearing. In competition with other laboratories in this development, we completed the project with a design and selection of materials that met the requirements of the sponsor. The successful completion of this project has resulted in placing another project to develop bearings to perform under more severe conditions.

Primary Metals Industry: A sponsor in this industry assigned us the task of developing a computer and percent-composition printer to operate from the output of an analytical instrument in their plant. This was successfully completed and placed in operation in their plant. This sponsor, after completion of this project, has continued to place new work with us.

Electrical Industry: We had the task of developing a superior ceramic material for the suppression of arcs in circuit breakers. New materials were developed and have gone into production in the sponsor's plant. This sponsor has continued to place work in the Laboratories.

Textile Industry: We had the task of modifying a sewing machine to perform operations which the manufacturer of the machine stated could not be done. After a few months' study and development program, we delivered a modified machine that did all the sponsor wanted.

Kellogg Foundation: The Projection Magnifier was developed under the sponsorship of the W. K. Kellogg Foundation. Patent applications covering this development have been filed with the United States Patent Office. In 1953 a contract was signed with the American Optical Company to manufacture and market this device.

A research laboratory's most valuable asset is a competent technical staff. This we have not only maintained, but have increased. The technical staff grew to an all-time high of 279 in 1953 (compared with 252 for 1952 and 211 for 1951.) The staff made 20 patent disclosures in 1953: 3 resulting from industrial projects, 8 from Institute-sponsored projects, and 9 from governmental projects. Thirty-four staff-written papers were published in technical journals and trade magazines; 16 papers were presented by staff members before professional societies and technical groups.

In cooperation with the American Society of Lubrication Engineers (Philadelphia Section), the Laboratories presented a 14-week course in advanced lubrication which was attended by more than sixty engineers from industries in this area.

MEMBERSHIP

The total membership of the Institute, including individuals with Library privileges under Company memberships, reached 6854 at the close of 1953, an increase of 228 members over the preceding year. A large number of our new members were proposed by those who were already members. The Institute is greatly helped by this continued interest and active participation in our efforts to build up our membership.

The Institute honored Charles Henry Howson on November 18th at a joint meeting with the Philadelphia Patent Law Association and presented him with a gold key and a gold membership card in recognition of fifty years of continuous membership in the Institute.

The Science Is Fun program, sponsored by this department, was started off by Donald H. Menzel, Director of the Harvard College Observatory, on February 27th, the publication date of his book "Flying Saucers," which was also the title of his talk. In June, members had a special preview of the Sun Oil Company's wonderful exhibit "Oil Serves America." The 20th anniversary of the opening of the Fels Planetarium was celebrated on November 6th, and the Science Is Fun program that evening honored James Stokley, its first director, who spoke on "The Eye of the Universe."

PERSONNEL

As of December 31, 1953, personnel of The Franklin Institute numbered 593, including the 41 at its Bartol Research Foundation. The Biochemical Research Foundation, of which the Institute is trustee, had 36, making a grand total of 629 employees. This was an increase of 22 over the previous year.

Efforts were made better to acquaint the Institute personnel with each other through functions held by the employees' Sunshine Club as well as a Christmas party given by the Institute.

During the year six employees joined the Armed Forces and are now scattered throughout the world.

One of the Institute's most loyal employees, Lewis Schlehner, who had been Building Superintendent for twenty years, retired and moved to Florida.

The deaths of two employees were recorded with deep sorrow: William E. Lister, Chief Engineer of the Maintenance Department, employed since December 16, 1933, and Walter S. Brown, Maintenance Engineer, employed since September 13, 1944.

The Personnel Department has been completely reorganized and is accomplishing its aim to give better service to the Institute and its employees. All personnel policies are in the process of being reviewed in order to bring them up-to-date, and many have been rewritten incorporating additional employee benefits.

PLANT OPERATIONS

Necessary alterations and construction work for the housing of laboratory rooms and Museum exhibits continued throughout the year.

Additional space, totalling 2200 sq. ft., was rented during 1953 on North 21st St. Construction work on a penthouse room on our main building, covering an area of 3100 sq. ft. to house the Network Analyzer project, was started in 1953. With these two new areas, total square footage in the Institute buildings has increased to over 296,000 sq. ft. Our buildings

in Swarthmore and Springfield Township (Delaware County), housing the Bartol Research Foundation, total over 27,000 sq. ft. This makes a total area of property, used by the Institute for its scientific and educational work, of over 323,000 sq. ft.

These figures in themselves are undramatic, yet they indicate a measure of the expansion of the Institute and its facilities. Our continued growth increases the demands made on our building and grounds staff, as well as on our facilities.

In October 1953, the Institute received an award for excellence in the protection of personnel and facilities from the Civil Defense Committee.

PUBLIC RELATIONS

The Public Relations Department continued to familiarize the public with the Institute and its activities through the use of the press, radio and television.

A total of 116 radio programs, both local and network, were presented by or for The Franklin Institute. This included "The Voice of The Franklin Institute," a weekly radio program over Station WDAS, broadcast throughout 1953.

Local and network television programs totalled 96, including a 15-week series of television programs on "The University of the Air" over WFIL–TV, produced and presented by the Public Relations Department.

The number of column inches of newspaper stories and pictures about The Franklin Institute, a rough way of measuring the amount of public notice given the organization, was gratifying.

The Institute News expanded its circulation, keeping pace with the increase in membership and other requests for this publication.

The number of speeches by staff members before scientific, industrial and civic groups surpassed last year's total. As in previous years, hundreds of inquiries about Franklin, his interests, and the phases of operation of the Institute were handled.

Nation-wide notices in press, radio and television were given special events outlined in preceding sections of this Report. Medal Day awards received special attention which resulted in additional recognition of The Franklin Institute and this internationally-known ceremony.

HOSTESS COMMITTEE

The Hostess Committee continued to earn our gratitude for its interest in the Institute. Continuation of the grounds-improvement program was the Committee's main project for 1953. In addition, Hostesses participated in the receptions preceding the dinners and lectures given by the Institute and contributed much to their success.

FRIENDS OF FRANKLIN

The group of public-spirited individuals and companies known as "Friends of Franklin" continued its generous support of the Institute, contributing $23,789 in 1953.

ENDOWMENTS

The past year marked a period of planning and development by the Endowment Department to seek various means by which additional funds for endowment and other purposes would ultimately accrue to the Institute. During 1953, more than $18,000 was contributed toward general endowment, laboratory and children's workshop equipment and specific endowment purposes, for which the Institute is most grateful.

FINANCES

Comparative results of financial operations for the years 1953 and 1952 are given in the following summarized statement of income and expenses of the Operating Fund adapted from the financial statements certified by our auditors (Messrs. Lybrand, Ross Bros. & Montgomery) whose report is available to members for examination in the office of the Treasurer:

	1953	1952
Operating Revenue		
Membership dues	$ 62,573	$ 60,722
Museum admissions and other museum income	136,361	131,782
Laboratory research projects	2,861,283	2,587,637
Other activities	54,221	49,495
	$3,114,438	$2,829,636
Operating Costs and Expenses		
Museum	$ 346,417	$ 322,397
Library, net of amounts transferred to other departments	78,210	70,594
Laboratory research projects	2,677,368	2,412,804
Other activities	71,382	75,473
Administrative and general expenses, net of amounts transferred to other departments	83,843	78,013
	$3,257,220	$2,959,281
Operating loss, before other income and charges	$ 142,782	$ 129,645
Other Income		
Income from endowment funds	$ 89,673	$ 87,413
Gifts from Friends of Franklin	23,789	25,243
Appropriation, Commonwealth of Pennsylvania	44,771	42,350
Other income	15,249	15,606
	$ 173,482	$ 170,612
	$ 30,700	$ 40,967
Other Charges		
Interest	$ 2,880	$ 4,589
Cafeteria expense	6,158	5,505
	$ 9,038	$ 10,094
Excess of income transferred to Operating Fund Balance	$ 21,662	$ 30,873

Included in the operating costs and expenses above are charges for depreciation and amortization of buildings and equipment amounting to $162,467 for 1953 and $162,511 for 1952.

The financial position of The Institute at December 31, 1953 as compared with December 31, 1952 is shown in the following summarized comparative statement, likewise adapted from the balance sheet contained in the auditors report:

Assets	Dec. 31, 1953	Dec. 31, 1952
Operating Funds		
Cash	$ 268,814	$ 149,180
Amounts receivable from laboratory research contracts	470,186	486,382
Other receivables	59,797	27,390
Inventories	48,592	44,297
Deferred charges	20,263	19,283
Total operating funds	$ 867,652	$ 726,532

Endowment Funds		
Investments at book values (market values $5,641,325 and $5,685,804, respectively)	$4,450,858	$4,389,306
Uninvested principal cash (overdraft in 1952)	39,613	(1,726)
Advances to operating funds	51,000	51,000
Advances to plant and property funds	45,000	45,000
Income cash	90,573	62,439
Total endowment funds	$4,677,044	$4,546,019
Plant and Property Funds		
Cash	$ 25,451	$ 90,784
Building, equipment, fixtures (less reserves for depreciation of $1,170,213 and $1,008,710, respectively)	3,925,966	3,651,089
Advances to operating funds	386,176	338,903
Total plant and property funds	$4,337,593	$4,080,776
Total Assets	$9,882,289	$9,353,327

Liabilities and Funds	*Dec. 31, 1953*	*Dec. 31, 1952*
Operating Funds		
Accounts payable, accrued expenses and deferred income	$ 328,413	$ 298,227
Amount due to endowment funds	51,000	51,000
Amount due to plant and property funds	386,176	338,903
Capital stock	10,430	10,430
Operating fund balance	91,633	27,972
Total operating funds	$ 867,652	$ 726,532
Endowment Funds		
General and restricted endowment funds and funds functioning as endowment including those of the Bartol Research Foundation	$4,586,471	$4,483,579
Undistributed and unexpended income	90,573	62,440
Total endowment funds	$4,677,044	$4,546,019
Plant and Property Funds		
Contributed funds	$3,952,309	$3,945,776
Funds received for purchase of special equipment	304,403	90,000
Amount due for special equipment	35,881	
Amount due to endowment funds	45,000	45,000
Total plant and property funds	$4,337,593	$4,080,776
Total Liabilities and Funds	$9,882,289	$9,353,327

Respectfully submitted,
By order of the Board of Managers,
S. WYMAN ROLPH,
President

COMMITTEE ON SCIENCE AND THE ARTS

(Abstract of Proceedings of Stated Meeting held Wednesday, June 9, 1954.)

HALL OF THE COMMITTEE,
PHILADELPHIA, JUNE 9, 1954.

MR. HOWARD STOERTZ in the Chair.

The following reports were presented for final action:

No. 3279: Henderson Medal.

This report recommended the award of the George R. Henderson Medal to C. Levon Eksergian, of Media, Pennsylvania, "In recognition of his invention and subsequent intensive development and application of the Disk Brake as applied to both self-propelled and high speed passenger cars in railroad service on this continent and to some degree abroad."

No. 3280: Levy Medal.

This report recommended the award of a Louis Edward Levy Medal, each, to Alfred C. Blaschke and Craig Lee Taylor, both of Los Angeles, California, "In recognition of their outstanding paper, 'The Mechanical Design of Muscle-Operated Arm Prostheses,' appearing in the November, 1953 issue of the JOURNAL OF THE FRANKLIN INSTITUTE."

No. 3281: Ballantine Medal.

This report recommended the award of the Stuart Ballantine Medal to Kenneth Alva Norton, of Boulder, Colorado, "In consideration of his contributions over a period of twenty-five years in the field of radio propagation through which our knowledge has been considerably increased by his measurements; our insight broadened by his theoretical work; our engineering calculations made easier by his charts and our broadcasting frequency allocations above 50 mc established more effectively through his guidance."

No. 3282: Clamer Medal.

This report recommended the award of the Francis J. Clamer Medal to William Justin Kroll, of Corvallis, Oregon, "In recognition of his invention of a method adaptable to the large scale production of cold malleable commercially pure titanium and zirconium."

JOHN FRAZER,
Secretary to Committee

JOURNAL OF THE FRANKLIN INSTITUTE

The following papers will appear in this JOURNAL within the next few months:

FLETCHER, S. W.: Philadelphia Leaders in Agriculture.
LINHART, J. G.: The Radiation Green's Function.
MOON, PARRY AND DOMINA EBERLE SPENCER: Calculation of Camera Exposure.
SWANN, W. F. G.: Acceleration to Cosmic Ray Energies by Betatron Action.
SCHONLAND, B. F. J. AND D. J. MALAN: Upward Stepped Leaders from the Empire State Building.
BARLOW, JOHN S., GEORGE W. FREY, JR. AND JOHN B. NEWMAN: Very Low Frequency Noise Power from the Lightning Discharge.
SEYMOUR, D. W. AND W. F. G. SWANN: A Determination of μ-Mesatron Rest Lifetime and a Verification of the Relativistic Expression for Variation of Lifetime with Momentum.
SCARLOTT, C. A.: Wind Tunnels—Why and Where.

MEMBERSHIP

ACTIVE MEMBERS ELECTED AT THE MEETING OF THE BOARD OF MANAGERS, JUNE 16, 1954

ACTIVE FAMILY

Nathan Dudnick
David Gelfand, M.D.
William U. Hohwieler
Arthur W. Perryman

ACTIVE

L. William Ballard, Jr.
Stanley E. Benson
Leroy Blum
Willard R. Calvert
Robert E. Derby
David Eldon, Jr.
Albert D. Emurian
Gordon S. Heylin
James F. Junge
Selman M. Kremer
Charles W. LaBelle
Roy Lyster
Wallace D. Newcomb
Robert F. Nowalk
William R. Rose
Albert Schatz
Harry H. Schmidt, Sr.
J. Ernest Spencer
Jack H. Van Sciver
Harry C. Viti
Walter R. Wilson

ACTIVE NON-RESIDENT

Henry R. Krueger

NECROLOGY

J. Harvey Byers, Esq. '44
George W. Elkins '36
Wendell F. Hess, D.E. '49
Wilfred Kurch '36

LIBRARY

The Committee on Library desires to add to the collections any technical works that members may wish to contribute. Contributions will be gratefully acknowledged and placed in the Library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat service. Photostat prints of any material in the collections can be supplied on request.

The Library and reading room are open from 9 A. M. until 5 P. M. on Mondays, Tuesdays, Thursdays and Fridays; 2 P. M. until 10 P. M. on Wednesdays; and 9 A. M. until 12 noon on Saturdays.

RECENT ADDITIONS

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The Franklin Institute, a privately endowed institution which exists today only because of the generous benefactions of its supporters, is justly proud of the dividends in human benefits accrued from the investments made through the years by its friends. The accumulation of many bequests for general endowment and income to be used where it will do the most good, is the most important and pressing need of The Franklin Institute today.

Checks should be made payable to The Franklin Institute and sent to The Franklin Institute, 20th and The Parkway, Philadelphia 3, Pennsylvania.

Transfer of property should be made to The Franklin Institute.

A typical form is:

I hereby give and bequeath to The Franklin Institute of the State of Pennsylvania the sum of.....to be used as The Board of Managers of The Franklin Institute may think advisable for the benefit of said Institution. (For the principal and income thereof to be devoted to.....).

Additional information on gift and memorial opportunities may be obtained through the above address.

NOTES FROM THE FRANKLIN INSTITUTE MUSEUM

A. C. CARLTON, DIRECTOR

FORMED STEEL

The late Colonel Ragsdale, when he was with the Budd Company, used to enjoy reciting his version of the origin of "shot" welding, a method the company adopted for welding stainless steel. There was a lugubrious preface in which the difficulties of welding stainless steel were recorded before he approached the episode which bred the thought that led to the conquest of the difficulty. A small girl one day presented her father with a shapeless mass of copper that had been a lightning rod. This rod had received a stroke of lightning and had fused under the terrific heat. But the house it had protected showed no trace of having been so much as scorched by this heat.

The incident gave rise to the thought that if the time element could be removed, if the heat applied in welding could be made instantaneous, then the material to be welded would not be affected any more than was the white paint on the house that had lost its lightning rod. The way Ragsdale told this story always ended with the conclusion that his company held the secret to the art of electric welding.

The Budd Company has had an exhibit in the Institute museum for a number of years, but it has been replaced recently by a new one which tells a little more about the welding of formed steel parts into a strong rigid whole.

The new exhibit tells more than what is gained by welding. It tells of the rigidity that can be given to steel by forming it to a required shape. The underbody of an automobile is used for illustration. This structure is well chosen for it is composed of seventy-three separate parts that must be joined together to make a rugged unity capable of withstanding great strains and stresses.

Two pieces of steel are first used to demonstrate how a normal flat sheet of the metal, held firmly at one end, is strong but highly flexible, and for this latter reason is unsuitable in that form for use in a car's underbody. The second piece of steel is of the same size and thickness, but it has been formed under a giant press to a shape that gives it the strength and rigidity necessary to be used as a cross member of the underbody.

All the separate parts of the underbody are shaped individually to the required forms, and have to be joined together. The joints are effected by electric spot welding. This method is adopted in preference to bolts or rivets for a number of reasons. It spares the time required for drilling holes, inserting the bolts, and tightening the nuts. Nothing

is added to the weight of the original parts, and the strength of those parts is not reduced by having holes drilled in the metal to receive the bolts. The structure is given a permanent rigidity in having no joints to work loose through vibration and the repeated jolting to which an automobile is subjected during the course of its use.

The actual welding is performed in the presence of the visitors. Two parts that are to be joined are firmly clamped together and the two electrodes are placed in position. A high electric current is shot instantly between the electrodes and, in passing through the steel, encounters a resistance that generates a heat sufficiently high to cause the two pieces of steel to fuse at that point and to become a part of each other.

The strength of the welded joint is then demonstrated. Although for museum purposes the welds are only subjected to a test of two hundred pounds, this weight is far, far below the strain to which the welds can be subjected and which they must constantly endure in actual use.

Everyone who uses an automobile and who is not familiar with its structural processes should see this demonstration, which will give him an excellent conception of the methods adopted primarily for providing him with an underbody that is distinguished for its strength and safety. The exhibit also serves to show how similar steel structures are assembled and held together, where maximum strength and minimum weight are matters of concern.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION

ELLICE McDONALD, DIRECTOR

AGEING AND ENZYME ACTIVITY

BY

M. H. ROSS AND J. O. ELY

In connection with investigations on age, diet and the enzyme activity of some particular enzymes in liver homogenates and of enzyme systems in tissue slices, it became desirable to know how the enzyme activity varies in normal rats at different ages.

Male rats of the Wistar strain were maintained on Purina Laboratory Chow [Crude Protein (min.) 23 per cent, Crude Fat (min.) 5 per cent, Crude Fiber (max.) 6 per cent, Nitrogen Free Extract (min.) 44 per cent]. The young rats, approximately 4 weeks old, weighed 35 to 45 gm.; the adult rats, 5 to 6 months old, 160 to 170 gm.; the old rats, approximately 21 months old, 450 to 500 gm.

Pieces of liver were homogenized immediately after removal from the animal, in the Waring Blendor at low speed for 30 seconds, or in one case, in the Potter-Elvejhem Homogenizer. Slices of liver were cut with the Stadie-Riggs slicer. Enzyme activity determinations were made on all the tissue preparations at 37° C. To enable the recalculation of the enzyme activities on bases other than fresh weight, the following information is given:

	Young Rat	Adult Rat	Old Rat
Total Nitrogen[a] mg./100 mg. fresh liver	2.67±0.050*	2.91±0.025	3.12±0.003
Moisture Content, %	72.2±0.23	70.6±0.16	68.9±0.13
Total Nuclei[b] per microscopic field	377.6±16.8	196.4±3.8	202.7±7.5
Hepatic Nuclei[b] per microscopic field	252.3±19.0	115.6±2.8	112.5±5.2
Mitochondria[c] ($\times 10^{-10}$)/gm. fresh liver	10.9±0.7	12.0±0.5	12.9±0.8
Mitochondria[d] per nucleus	303±36	623±39	603±25

[a] Determined according to Ma and Zuazaga (1) after homogenization of liver in water in Waring Blendor for 30 seconds.

[b] Counted in liver sections. Livers from each group processed and embedded together and cut at 4 microns by the same stroke of microtome knife. Total number of cells calculated by adjusting for the number of binucleated cells for each age level according to values reported by St. Aubin (2).

[c] Counted according to Shelton et al. (3).

[d] Calculated from number of mitochondria/gm. of liver and the number of nuclei/gm. of liver. The number of nuclei/gm. of liver determined by counting nuclei in suitably diluted portions of 5 per cent cold citric acid homogenate made with the Potter-Elvejhem homogenizer.

* Mean ± S. E_{mean}.

ENZYME ACTIVITY IN RAT LIVER HOMOGENATES

With increase in age, the maximal activities of 8 of the 11 individual enzymes increased, 2 decreased and one remained unchanged (Table I). The change in enzyme activity with age must be related to changes in enzyme content of the same kind of cell rather than to changes in type of cell, since the change in population of hepatic to non-hepatic cells did not exceed 8 per cent from young to old rats.

TABLE I.—*Enzyme Activity in Fresh Liver Homogenates from Normal Rats.*

	Units	No. of Rats	Young Rat	Adult Rat	Old Rat
Adenosinetriphosphatase (4)					
Without Ca^{++}	ATPase units	37	1.65±0.17*	1.90±0.22	2.06±0.21
With Ca^{++}	ATPase units	37	4.69±0.37	6.88±0.29	9.81±0.29
Pyrophosphatase (5)	γP liberated/mg. liver/15 min.	43	7.15±0.45	17.05±0.68	16.91±1.04
Acid Phosphatase[a]	γP liberated/mg. liver/hr.	91	14.60±0.35	14.57±0.16	14.26±0.48
Alkaline Phosphatase[b]	γP liberated/mg. liver/hr.	65	1.63±0.06	1.09±0.09	0.68±0.03
Dehydrogenase without added substrate (6)	γFormozan produced/mg. liver/10 min.	45	0.15±0.02	0.31±0.02	0.46±0.05
Succinic dehydrogenase (6)	γFormozan produced/mg. liver/10 min.	60	0.86±0.03	1.09±0.03	1.09±0.03
Lactic dehydrogenase (6)[c]	γFormozan produced/mg. liver/10 min.	79	0.41±0.02	0.66±0.02	0.73±0.02
Malic dehydrogenase (7)[d]	$\mu l.O_2$/mg. liver/hr.	48	16.22±0.51	17.10±0.37	19.12±0.39
1(−) Histidase (8)	Histidase units/gm. liver	46	0.75±0.02	1.42±0.04	3.32±0.16
Cathepsin (9)	$(C.u.)^{Mb} \times 10^{-4}$	54	12.44±0.32	9.92±0.38	8.02±0.34
d-Amino oxidase (10)[e]	$\mu l.O_2$/mg. liver/hr.	22	149.9±14.3	287.6±10.7	347.3±28.7
Fructokinase (11, 12)	mg. Fructose disappeared/ 100 mg. liver	31	0.70±0.03	0.88±0.04	1.18±0.10

[a] Na beta glycerophosphate as substrate, 5 mg./ml. final concentration, in a 0.067*M* sodium acetate-acetic acid buffer at pH 5.0. Incubation period, one hour.
[b] Same as *a* but 0.050 *M* veronal buffer at pH 9.1.
[c] Lactic acid substituted for succinic acid.
[d] Sodium malate, 0.05 *M*, final concentration.
[e] Dixon-Keilin differential manometer employed.
* Mean ± S.E.$_{mean}$.

It had been shown by others that rat liver arginase (13), xanthine oxidase (14), monamine oxidase (15), succinoxidase (16), choline oxidase (16), fatty acid oxidase (17), transaminase (18), glutaminase II (19), asparaginase (Inherent) (19), and asparaginase II (19) increased with age and glutaminase I (19) and cytochrome oxidase (20) decreased. Evidently the activities of most of the hepatic enzymes increase with age. Since the concept of ageing is that of a generalized and progressive decline in the activities of the cell, it is remarkable that the activity of so many enzymes increases with age.

ENZYME ACTIVITY IN FRESH RAT LIVER SLICES

With increase in age, the activity of the system of enzymes involved in oxygen uptake diminished in the absence of added substrate; however, it rose in the presence of added substrate (sodium succinate). Autoglycolysis decreased with age but fructolysis increased (Table II).

TABLE II.—*Enzyme Activity in Fresh Liver Slices from Normal Rats*

	Units	No. of Rats	Young Rat	Adult Rat	Old Rat
Oxygen Uptake[a]					
With no added substrate	$\mu l.O_2$/hr./mg. liver	83	1.51±0.04*	1.20±0.03	1.03±0.03
With sodium succinate 0.05 *M* final conc.	$\mu l.O_2$/hr./mg. liver	36	2.80±0.09	2.97±0.10	3.23±0.10
Autoglycolysis[b]	$\mu l.CO_2$/hr./mg. liver	31	1.24±0.06	0.86±0.07	0.57±0.07
Fructolysis					
Fructose 0.015 *M* final conc.	$\mu l.CO_2$/hr./mg. liver	31	0.89±0.09	1.16±0.05	1.54±0.14

[a] Determined in Krebs-Ringer phosphate buffer at pH 7.3 in Warburg manometers in 100% oxygen atmosphere.
[b] Determined in Krebs-Henseleit buffer at pH 7.6 in Warburg manometers in an atmosphere of 95% nitrogen: 5% carbon dioxide.
* Mean ± $S.E._{mean}$.

The increase in fructolysis during ageing is in accord with the report by Albanese et al. (**21**) that fructose is more readily metabolized by older individuals. The cause of the low rate of oxygen uptake, of the low rates of autoglycolysis and of the reported (**22**) low rates of anaerobic glycolysis may be the inadequate amounts of substrate rather than the change in the amount of enzyme.

Since a small change in substrate concentration produces a great change in activity *in vitro* if the enzyme is not saturated (**23**), a small change in substrate concentration, *in vivo*, where very small amounts of substrate are present, may produce a great change in activity. Therefore a decrease in substrate content which was shown (**24**) to occur may reduce the amount of enzyme activity even though there is ample enzyme present.

The changing enzyme activity and the changing substrate content during ageing may be the dominant factors in the tissue and metabolic changes that occur with ageing.

SUMMARY

The influence of ageing of normal rats on the activity of some particular enzymes in liver homogenates and of some enzyme systems in liver slices was investigated. In the presence of adequate substrate, the activity of nearly all of the enzymes was found to increase with increasing age.

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BOOK REVIEWS

THOMAS YOUNG, NATURAL PHILOSOPHER, by Alex Wood, completed by Frank Oldham. 355 pages, port., 15 × 22 cm. New York, Cambridge University Press, 1954. Price, $6.00.

Here is an admirable book for which a cordial welcome seems assured. Thomas Young lived at that time when the range of knowledge was almost within the compass of a single mind. In that respect he may be said to belong to the eighteenth century, but his discoveries in the early decades of the nineteenth century reveal him as a link between the past and the present ages of science.

Trained in medicine at London, Edinburgh, Cambridge, and Göttingen, Young's roving mind carried him far beyond the limits of his profession to embrace original investigations in natural philosophy (as physics was called), mathematics, the mechanical arts, and languages. He was no dilettante. For his doctoral dissertation at Göttingen he produced a thesis on sounds and the human voice that he connected with his earlier work on optics by suggesting that both sound and light were wave vibrations, colors being analogous to notes of different frequencies. It was generally accepted that sound consisted of wave vibrations, and Young presumed that light consisted of similar longitudinal vibrations in a luminiferous aether which pervaded all space. He pointed out that light from a weak source travelled just as fast as that from an intense source, a fact that could be accounted for more easily by the wave theory of light than the particle theory.

Young performed an experiment in which two light beams were allowed to interfere, producing alternate light and dark bands where one beam reinforced or cancelled the other. Later, in completing his explanation of the optical phenomena Young, with Wollaston, verified Huyghens' analysis of the phenomenon of double refraction observed with crystals of Iceland spar.

In furtherance of these investigations Young communicated the results to Arago who conveyed them to Fresnel, and this was the basis of Fresnel's essay on the subject of optical diffraction that gained for him the prize offered by the Academy of Sciences.

Young came into conflict with the ideas of Humphrey Davy who presumed from experiments that heat was "a peculiar motion, probably a vibration of the corpuscles of bodies." Young advanced a different mechanical theory of heat, claiming, from the study of the radiant heat emitted by red hot bodies and the heating effect of the infra-red region of the spectrum, that heat might be a wave vibration like light. This received little support at the time and the material theory of heat, the idea of caloric heat, was generally received until the 1850's.

Space does not permit us to review other important achievements of the versatile Thomas Young, but a few words must be said upon his labors on the Rosetta stone. The credit for having deciphered the hieroglyphic and the Coptic scripts is given unreservedly to J. F. Champollion, but the author of this book makes out a convincing case that Champollion owed much to Young's earlier work on the famous stone.

Some idea of the versatility of this extraordinary man may be gathered from the articles Young wrote for the *Encyclopaedia Britannica*. In addition to his well known article on Egypt he contributed others on Annuities, Bathing, Bridges, Carpentry, Cohesion, Chromatics, Herculaneum, Hydraulics, Languages, Life Preservers, Road Making, Steam Engines, Tides, Weights and Measures, and, with Arago, one on Double Refraction. These were supplemented by forty-five biographical notices, or sixty-one articles in all covering 380 quarto pages.

A re-assessment of Young's position in the world of science is overdue. He has been slighted by modern biographers, but he has been fortunate in the end. Dr. Wood is reputed to have devoted forty years of his

leisure to collecting new material on Young's life and work, and in verifying the material used by Lees, Gurney, and Peacock in their earlier biographies. The result is a fine scholarly work, ably completed by Mr. Oldham after Dr. Wood's death. We can heartily recommend this fascinating study of a remarkable man and his work. T. C.

ZIRCONIUM—METALLURGY OF THE RARER METALS, No. 2, by G. L. Miller. 382 pages, diagrams, 15 × 22 cm. New York, Academic Press, Inc., 1954. Price, $7.50.

The current series of texts on the rarer metals edited by H. M. Finniston is designed to cover some of the rarer metals. This book like its predecessor, "Chromium," starts out by a discussion on the history, occurrence, consumption and use of this metal. A large portion of the first third of the book is devoted to the extraction of zirconium from its ore, purification, and production. The development of these phases has taken place in the last thirty years and zirconium has moved from a position of a metal having very little practical significance to one playing a critical role in the rapidly growing field of nuclear physical applications.

Another book on zirconium has recently been published. This is the American Society of Metals publication, "Zirconium and Zirconium Alloys." This is a symposium consisting of twenty-one papers on specialized subjects. There is, of course, considerable duplication of material. In general, there is more detail on the subjects covered in the A.S.M. symposium but it is of much more limited scope than the text being reviewed. For example, the A.S.M. symposium covers several binary systems in detail, whereas Dr. Miller reviews the data available on a great many binary systems of zirconium.

An especially well detailed chapter is that on the melting of zirconium. This metal reacts quite strongly with the common gases and refractory materials used to melt it in. This of course poses a serious problem if it is desired to produce a relatively pure melt. The author discusses the various melting methods for handling zirconium and illustrates the equipment in each case with great detail.

In view of the importance of zirconium in the field of atomic energy, it would seem that the author might well have devoted some space to the declassified aspects of this subject. Of course, knowing that zirconium is of high melting point, good corrosion resistance and has only a slight tendency to absorb slow neutrons, enables one to conjecture as to its possible uses in this direction. The difficulty with subjects dealing with atomic energy is that the scientist is usually afraid to discuss any aspects of his subject pertaining to it even if it is unclassified material.

Generally this book is well organized and contains a complete up-to-date compilation of existing knowledge on zirconium. It should prove an invaluable aid to those working with, or interested in, this rather unusual metal. It is hoped that the same high standards will be maintained in the remaining texts to be published in this series.

R. L. SMITH

NUCLEAR RADIATION PHYSICS, by R. E. Lapp and H. L. Andrews. Second edition, 532 pages, illustrations, 15 × 22 cm. New York, Prentice-Hall, Inc., 1954. Price, $6.75.

New significance is associated with the second edition of "Nuclear Radiation Physics" in light of what has happened in the past few months. More and more there is a need for the understanding of what takes place when man tampers with the nucleus of the atom. In this book the reader will find the answers.

"Nuclear Radiation Physics" is the second edition of a book published in 1948. The authors are eminent in their respective fields. Dr. Howard L. Andrews of the National Health Institute at Bethesda, Maryland, is an authority on the biological effects of high energy radiations and Dr. Ralph E. Lapp has had a notable career in the field of atomic energy, at one time heading up the nuclear physics branch of ONR. Together they team up to produce a readable and intelligent book on nuclear physics.

The tremendous development in this field has necessitated the complete revision of the first edition so that the new material in the science could be incorporated and the book be brought up-to-date.

The first seven chapters of about 200 pages are a discussion of the particles of modern physics and in a succinct manner the field is unfolded so that the reader acquires a feel for the multiplicity of the particles which the physicist must not only explain but also try and weave into a coherent pattern. Of this, they write: "It is generally agreed that a radically new discovery is required to unify the present divergence in our understanding of nuclear structure."

The authors add little known but significant statements which enhance the value of the book. For instance, for some time it has been known that even the stable elements might undergo radioactivity. They show that $_{57}La^{138}$ which was once thought to be completely stable is radioactive. They indicate that all elements might break down radioactively but our detection equipment must be improved to prove this.

Throughout the book the authors have made use of an ingenious device of performing illustrative problems in the body of the text to show the application of a particular law. There is nothing which will bring home a point like an illustration. These are found in profusion and add to the understanding of the picture they paint.

In the treatment of alpha particles they conjure up a simple but important picture. They say: "Let us focus attention upon a specific instance of alpha emission—an alpha particle emitted by a U^{238} nucleus. For the sake of simplicity we shall take the nucleus as 10^{-13} cm in radius and the velocity of the alpha particle inside the nucleus as 10^9 cm/sec. The physical picture we then obtain is the alpha particle in a constant state of motion among the nucleons, making about 10^{21} traversals of the nucleus every second. Thus the alpha particle appears at the nuclear surface 10^{21} times every second and tries to escape. In the case of the U^{238} we know experimentally that the half life is 4.5×10^9 years and the disintegration constant is 4.9×10^{-18} sec^{-1}. Then on the average the alpha particle would have to make on the order of 10^{39} attempts before it leaves the nucleus." Here is an explanation of the escape mechanism of an alpha particle from the nucleus. This is but one of many examples showing the simple approach to a most complex problem.

Chapters 8, 9, and 10 deal with instruments used in nuclear physics. They begin with detection devices and go through to the giant accelerators so much in the news today. Chapter 11 deals with induced nuclear transformations and Chapter 12 is devoted to neutron physics.

Chapters 13 and 14 deal with nuclear fission and the companion subject, nuclear power. In the latter chapter there is a section on the economic aspects of nuclear power and energy resources.

The last three chapters deal with radiation problems: the first with radiation measurement techniques, the second with tracer techniques and the last with radiation health problems.

"Nuclear Radiation Physics" is one of the finest books on this subject which this reviewer has ever seen. I. M. LEVITT

BIOLOGICAL EFFECTS OF EXTERNAL X AND GAMMA RADIATION, PART 1, edited by Raymond E. Zirkle. 530 pages, illustrations, 16×24 cm. New York, McGraw-Hill Book Co., Inc., 1954. Price, $7.25.

This important volume is a collection of articles representing original research and organized into 22 chapters written by 31 contributing authors including its editor, Raymond E. Zirkle. It is one of a series of volumes recording the radiobiological research stemming from the Plutonium Project as completed under the Manhattan Project and the Atomic Energy Commission.

Chapters 1 through 6 (242 pages) are concerned with the effects of long-continued total-body gamma irradiation on mice, guinea pigs and rabbits. Treated in these chapters are descriptions and plans of the experiments and the results of gamma irradiation on life span, weight and blood in these laboratory animals; also breeding behavior, pathology, carcinogenesis and the applicability of results to problems of human protection. Chapters 7 through 12 (130 pages) deal with the effects of total-body x-irradiation on rabbits in regard to mortality after single and paired doses, the hematological effects (including leucocytes), irradiation effects on a preexisting induced

anemia caused by both phenylhydrazine and bleeding and conclude with an account of histopathological studies. Chapters 13 (published in abstract, one page, since the article appeared elsewhere) and 14 (14 pages) pertain to the x-irradiation effects on dogs: studies on an anticoagulant of blood with hemorrhagic tendency and an electrophoretic study of x-irradiation effects on the plasma protein pattern. Chapters 15 through 17 (49 pages) consider the effects of x-irradiation on enzyme activity, tissue metabolism of rats and permeability of the small intestine of these animals to glucose. Chapter 18 (published in abstract, two pages, since the article appeared elsewhere) deals with the x-irradiation effects on immunity and Chapters 19 and 20 (34 pages) describe the x-irradiation induced changes in ultraviolet absorption spectra of urine of dogs. Chapter 21 (44 pages) describes the effectiveness of drugs in preventing or alleviating x-ray damage in rabbits and mice and the concluding chapter 22 (6 pages) gives the methods of exposure to x-rays of the following: rabbits, rats, guinea pigs, mice, dogs, chickens, Amphiuma, newts, goldfish, Drosophila imagos and eggs and enzyme preparations. However, additional information concerning methods of x-irradiation is given by the authors of the various chapters.

This highly informative volume of original papers will prove to be a valuable reference work for all persons interested in the field of radiobiology. Of value to the reader is the fact that each article is prefaced by an abstract. With three exceptions, each article is documented with literature citations appearing at the end of the chapter.

The editor and authors are to be congratulated in bringing this vast amount of important and original radiobiological information into one volume. Tables and figures (especially graphs) representing the research are abundant. In the opinion of this reviewer, the index, while adequate, could well have been expanded to add to the greater usefulness of this book. Typography, illustrations, format and binding reflect credit to the publisher.

RALPH WICHTERMAN

INTRODUCTION TO EXPERIMENTAL PHYSICS, by William B. Fretter. 349 pages, diagrams, 16 × 24 cm. New York, Prentice-Hall, Inc., 1954. Price, $9.00.

This is a book on modern experimental physics with the emphasis upon the techniques of nuclear physics. The 32 chapters are divided into two main sections—one on general subjects such as electrical measurements, pulse circuits, magnet design, vacuum techniques, particle detectors and one on more specialized topics such as accelerators, mass spectroscopy, optical spectroscopy, microwave spectroscopy, molecular beams, magnetic resonance, pile techniques, low temperatures. Finally, there are chapters on laboratory hazards and design of experiments.

A great deal of valuable information for the experimentalist is found in this book. The author intended it for graduate students and tried to cram in as many tricks of the trade as he could. He has included many new and useful techniques but has omitted many standard methods to conserve space. In his preface, the author states that this was not intended to be a *Handbuch*. Obviously, there is going to be the specialist who feels that his subject has not been given sufficient space.

Of the 15 chapters on specialized apparatus and techniques, ten can be said to be in nuclear physics. Solid state physics seems to be somewhat neglected. Even so, it might be expected that many students at our smaller schools will be somewhat envious of those schools which are equipped to demonstrate the major equipment discussed in these 15 chapters.

The style is intentionally terse but not unpleasant. As a result, there is very little fat on the meat of the text. It is assumed that the graduate student is mature and will obtain most of the explanatory matter in standard references. In some chapters, however, the author could have explained more fully why and where certain techniques are used.

The book is a result of notes taken in a series of lectures by many experts in various fields. There is some evidence of this in the text; for example, some of the graphs are too much like sketches on the blackboard,

and give an inaccurate idea as to relative values. Furthermore, there is an unevenness of treatment in the various chapters. Some are quite detailed while others are only cursory.

As a whole, this new book on techniques is welcome and should prove useful to a large number of students. LEONARD MULDAWER

INTRODUCTORY CIRCUIT THEORY, by Ernst A. Guillemin. 550 pages, diagrams, 16 × 24 cm. New York, John Wiley & Sons, Inc., 1953. Price, $8.50.

For many years Professor Guillemin's two-volume book "Communication Networks" has occupied the lead position in its field as a standard work for advanced students. *Introductory Circuit Theory* may well occupy as enviable a position in the years to come because of its treatment of the basic principles and concepts of electric circuit theory and network synthesis. Unique in Prof. Guillemin's approach is the philosophy, so true and yet so often overlooked by less erudite and sensitive authors, that basic concepts and processes of analysis are the same when presented to undergraduate students majoring in electronic engineering (for whom this book is written) as when presented to advanced graduate students. Consequently, when the basic ideas and principles are introduced in this book, stress is also laid on the reasons why these are fundamental. Developed in the book in this way, among others, are the reasons for the independence of certain combinations of mesh currents and node voltages, for the impedance concept and the complex frequency plane representation, for transient phenomena, and for the principles of duality.

Professor Guillemin spent five years planning and using the material in this book and developing the particular mode of presentation of material. His experience is imprinted in each chapter and in the book as a whole. Since his experience has shown that physics students likewise should have, but seldom receive, training in the same principles required by electrical engineering students, he has designed the book so that selected topics may be used in a one semester course for the former, and the complete book as a two semester course for the latter.

The order of topics is somewhat as expected from the point of view of the field of electric circuit theory and synthesis. The two introductory chapters consider ways for selecting appropriate and desirable variables, on the loop or node basis, and the equilibrium equations for networks. Having established a representation, the next step is to solve the equations. Chapter 3 is concerned with formal mathematical methods and network theorems which expedite the process of solution. As in the previous chapters, somewhat more material is included than is required at an introductory level. Professor Guillemin notes, however, that this is a saving of effort in the long run, because at a later time, less review will be required to fully appreciate and understand this additional material.

Transient responses of circuit elements and simple networks to unit step and unit impulse functions, considered in Chapters 4 and 5, introduce the reader to a bit of reality. Knowledge of such responses is basic to an understanding of physical network situations, and should be learned and remembered. It is not until the sixth chapter that the author considers the reader to be prepared to understand the behavior of simple circuits in the sinusoidal steady state. Now are introduced the impedance and admittance concepts and the complex frequency plane representation. These are the real building blocks upon which are based almost all methods for synthesizing networks. They are applied to more general networks in the eighth chapter, after a digressive one treating the subject of power from the point of view of stored energy functions and dissipative functions. The last two chapters expand the concepts of the complex frequency plane and generalize the circuit equations and energy relations. Networks are synthesized after assuming pole-zero configurations for the desired transfer functions and the principle of duality is stressed.

Professor Guillemin's book is highly recommended as a textbook. Any instructor adopting this book is bound to be kept on his toes, technically and pedagogically. It is also well suited to serve the needs of practicing electrical engineers who appreciate new explanations and a fresh approach to matters old. S. CHARP

THE STATISTICAL APPROACH TO X-RAY STRUCTURE ANALYSIS, by Vladimir Vand and Ray Pepinsky. 98 pages, illustrations, 22 × 28 cm. State College (Pa.), The Pennsylvania State University, 1953. Price, $1.50 (Paper).

The principal motivation for this book (or more properly, monograph) was a need, in the opinion of the authors, for a "critical review" of the statistical approach to crystal analysis as put forth by Hauptman and Karle.[1] It could never be denied that the work of Hauptman and Karle has been reviewed critically; in fact, it could be argued that Vand and Pepinsky have been unjustifiably harsh. Be that as it may, the results of the detailed analyses presented show that "the extensive claims of Hauptman and Karle are unfounded, and in particular that their statement—that a general solution of the phase problem has been achieved—is quite without justification."

The proof of this conclusion alone makes this monograph a more than worthwhile work from the point of view of X-ray analysts. Vand and Pepinsky, however, are thorough scientists and much too interested in this field to content themselves with disproving claims of other workers. They present here, in addition, a more general investigation of the statistical approach. They give derivations of general probability formulae which are more powerful than those of Hauptman and Karle and show that the Hauptman-Karle formulae are, in many cases, derivable as rather special approximations of these. In the course of these accomplishments Vand and Pepinsky have given important new insight into the meaning and limitations of the statistical approach.

The studies presented in this monograph were made possible by grants from the National Institute of Arthritic and Metabolic Diseases of the National Institute of Health, and the Rockefeller Foundation, and a contract with the Office of Naval Research. These agencies are justified in considering these monies well spent.

F. E. JAUMOT, JR.

[1] Published as a series of papers in *Acta Crystallographica*, Vols. 5, 6, and 7 (1952-53-54). Also as Monograph No. 3, A.C.A., The Letter Press, Wilmington, Del. (1953).

INSTRUMENT ANALYSIS, by John H. Harley and Stephen E. Wiberly. 440 pages, illustrations, 15 × 24 cm. New York, John Wiley and Sons, Inc., 1954. Price, $6.50.

"In instrumental analysis, a physical property of a substance is measured to determine its chemical composition. It is a common fallacy that in instrumental analysis the analytical chemist pushes a button and the machine does the rest. However, in most instrumental work, a higher order of technique is required than in conventional methods, and considerable skill is needed to interpret the results."

The need for an acceptable text in this field has been very evident to all those who are interested in the subject. This need has, from time to time, been partially satisfied with the advent of a few new texts; but, for the most part, one was forced to the tedious task of correlating journal articles which is time consuming at best.

New or unpublished methods in the field have not been introduced by this text; however all importance has been placed on classifying the common techniques. Much emphasis must be made on the organization of the text. First, there is a discussion of the theory involved; second, an examination of the components of each instrument; third, a consideration of various commercial instruments; and fourth, typical procedures and applications. Limitations as well as advantages of the different methods are carefully considered. Each chapter is concluded with a bibliography to afford one the benefit of immediate reference to each field.

The text is composed of twenty-two chapters and nine important appendices. It is well illustrated by photographs, schematic diagrams, graphs and informative tables.

The natural movement from the simple to the complex is a strong recommendation for the text. Ten chapters are devoted to discussion of absorption and emission spectroscopy where many new techniques are considered including a treatment of echelle spectroscopy. "Flame Photometry" comprises another chapter, and two chapters are on pH measurements. The five succeeding chapters are concerned with potentiometric, conductometric, amperometric and high frequency titration methods together with po-

larography. The text concludes with chapters on "X-Ray Analysis," "Mass Spectrometry" and "Nuclear Radiation Measurements." The final chapter is one of laboratory experiments. Experiments have been selected from current literature which deal with the analyses most frequently performed.

The text is written assuming that the reader has a good basic knowledge of analytical, organic and physical chemistry, and is therefore a pleasure not to waste space with elementary concepts. This effort to begin at a more advanced step, however, does give rise to a weakness in definitions.

PHYLLIS A. PARKIN

INDUSTRIAL INORGANIC ANALYSIS, by Roland S. Young. 368 pages, diagrams, 15 × 22 cm. New York, John Wiley & Sons, Inc., 1953. Price, $5.75.

Written for the industrial analytical chemist, this book can be useful in laboratories where inorganic analysis may be an occasional requirement. It is easily readable and well-organized. A short chapter is devoted to each element. Included are a brief historical introduction to the inorganic substance, some basic theory of the analytical process, and details of the procedure. Alternative procedures are described.

The final chapter departs somewhat from the general form, and describes procedures used to determine such industrial analytical requirements as acidity of oils, gas analyses (CO_2, CO, O_2 in metallurgical operations), industrial water analyses, and several other procedures. Figures and several reference tables are included to assist in describing some of the required apparatus. The references are adequate.

S. MUCHNICK

EXPERIMENTAL INORGANIC CHEMISTRY, by W. G. Palmer. 578 pages, 15 × 23 cm. New York, Cambridge University Press, 1954. Price, $9.00.

Dr. Palmer has chosen this book to start something of a revolution in the staid old methods of teaching inorganic chemistry. It has been his experience during many years of teaching that inorganic chemistry and its laboratory work stirs up about the same level of intellectual curiosity in the average student as a blank wall. Further, the author feels that the teaching method, and not the subject matter, is at fault. He cites the example of organic chemistry which has proved to be the least dull and monotonous field of chemistry to students. Organic chemistry is taught primarily in the laboratory with relatively little classwork; hence Dr. Palmer plans to teach inorganic chemistry in the same manner. His method of improving student interest is to select syntheses that require proficiency in experimental technique and result in end products that are far from the ordinary inorganic compounds prepared in the laboratory. For example, the student prepares and analyzes compounds like sodium pentacyano nitrosylo-ferrate, boron-phosphoric anhydride, neodymium oxalate, and titanic acid. The emphasis is heavily on the internal and external crystallographic nature of the compounds synthesized as well as the mechanisms of the reactions involved.

The book itself is divided into two main parts. The first section is titled "Introduction" and is also divided into parts; the first part deals with atomic and crystallographic structure of elements and compounds, and the second part is directed toward an explanation of methods of crystallization, chemical analysis, and analysis by electrochemical techniques. The second section of the book, comprising about three quarters of the entire book, contains the preparations and analyses of compounds arranged, on the basis of the element being studied, in groups as they appear in the periodic table. At the beginning of each set of preparations for a periodic group is a brief discussion of the general features of the elements in the particular group. The end of the book contains a subject index as well as something of an innovation for a textbook—a formula index of the synthetic preparations.

It is the opinion of the reviewer that the author has selected a method of presentation and a series of experiments that should not only hold the student's attention but also may even cause him to seek out further information by himself on specific items. The experiments are chosen such that the cost of materials and equipment is low enough for almost any university laboratory to afford. This book is recommended specifically to chemistry teachers for consideration as a supplement to their existing course work and perhaps even as a substitute for it.

DONALD H. RUSSELL

BOOK NOTES

LUBRICATION OF INDUSTRIAL AND MARINE MACHINERY, by William Gordon Forbes, revised by C. L. Pope and W. T. Everitt. Second edition, 351 pages, illustrations, 16 × 24 cm. New York, John Wiley & Sons, Inc., 1954. Price, $6.50.

Revision of this standard work was undertaken by C. L. Pope and W. T. Everitt in order to bring up-to-date the material originally published in 1943 by W. G. Forbes. They have followed the original purpose—to provide a usable reference book for lubrication engineers, with a minimum of repetition and a maximum of useful information. The first half of the book deals with the chemistry of lubricants, their refining, compounding, etc.; the second half is devoted to the lubrication requirements of various types of machinery. The book is recommended to all lubrication engineers and users of machinery. It is authoritative and easy to read.

MATHEMATICS IN AGRICULTURE, by R. V. McGee. Second edition, 208 pages, 15 × 22 cm. New York, Prentice-Hall, Inc., 1954. Price, $4.00.

In the second edition of this elementary mathematics book for agriculture students, the changes include more emphasis on problems dealing with machine power and electricity on the farm, revision of problems to bring them in line with current prices and farm practices, and expansion of the treatment of algebra. The mathematics involved ranges from the simplest operations such as adding feet and inches, to logarithms and the use of the slide rule. A section of tables related to agriculture is appended, as are four-place log tables.

ENERGY TRANSFER IN HOT GASES. NBS Circular 523. 126 pages, illustrations, 15 × 24 cm. Washington, Government Printing Office, 1954. Price, $1.50.

In September, 1951, the National Bureau of Standards sponsored a symposium on Energy Transfer in Hot Gases. The sixteen papers are now published and ready for distribution. Outstanding contributors discuss the problems of radiation from flames and hot gases, as well as the chemical and physical mechanisms governing transfer of energy therein. Both theory and practical applications are treated in a thorough manner. All engineers interested in heating devices, jet motors, gas turbines and internal-combustion engines will profit from a study of these papers.

POLYMER DEGRADATION MECHANISMS. NBS Circular 525. 280 pages, diagrams, 15 × 24 cm. Washington, Government Printing Office, 1953. Price, $2.25.

The seventeen papers comprising this volume were presented at a symposium sponsored by the National Bureau of Standards in 1951. The authors include world-wide authorities in the field and the papers cover thoroughly the progress made up through the date of the symposium. In view of the growing demand for synthetic products in our national economy, research on polymer degradation to increase the life of polymeric materials is of utmost importance. The present papers cover degradation and aging of such polymers as polystyrene, polymethyl methacrylate, polyvinyl chloride, vinyl chloride, polyacrylonitrile, polyethylene, and cellulose esters. The book should be in the library of all polymer scientists.

CHARACTERISTICS AND APPLICATIONS OF RESISTANCE STRAIN GAGES. NBS Circular 528. 140 pages, illustrations, 15 × 24 cm. Washington, Government Printing Office, 1954. Price, $1.50.

The eleven papers presented at the NBS Symposium on Characteristics and Applications of Resistance Strain Gages are published as NBS Circular 528. The increasing use of resistance strain gages in the study of materials and structures assures this small volume of a wide circulation. The symposium papers cover both theoretical and experimental work on resistance strain gages, along with applications such as measurement of acceleration, impact, large static forces, etc., determination of strain distribution in structures, and the determination of dynamic properties of materials.

TROPICAL METEOROLOGY, by Herbert Riehl. 392 pages, diagrams, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1954. Price, $8.50.

This new text is designed for an undergraduate course in tropical meteorology; however, it may be used also on the graduate level as a one-semester course. It is the first full text on this specialized phase of meteorology and as such will be welcomed by teachers and students, as well as by working meteorologists. The study of weather in the tropics is essential for military installations located at low altitudes, for ordinary methods of predicting weather do not hold in the tropical regions. The text covers such topics as winds, tropical rainfall, temperature (both surface and upper air), weather analysis, divergence and vorticity, waves in the easterlies, low-latitude disturbances, and tropical storms. The final chapter discusses the present status of the general-circulation theory and its breakdown under tropical conditions.

HOW TO USE PORTABLE POWER TOOLS, by Maurice H. Reid. 210 pages, illustrations, 14 × 21 cm. New York, Thomas Y. Crowell Co., 1954. Price, $2.95.

Portable power tools have made it possible to save many hours formerly spent in laying out a job, marking, and carrying work back and forth to the bench. The professional and amateur carpenter will find, in this useful book, descriptions of all kinds of portable power tools, methods to use them and how to take care of them. A valuable appendix contains a table of woods, giving their properties and uses, a table of drill and bit sizes, and abrasive charts for finishing jobs. The book should prove a handy reference to the millions of people who use portable power tools.

THE STRUCTURE OF TEXTILE FIBERS, edited by A. R. Urquhart. 165 pages, plates, diagrams, 16 × 25 cm. Manchester (England), The Textile Institute, 1953. Price, $1.75.

Composed largely of revised articles previously published in the *Proceedings* section of the *Journal of the Textile Institute* in 1949 and 1950, this volume is intended for the beginning student and for workers in the textile industry. It is written, insofar as possible, in non-scientific language;, however, as in any technical subject, many specialized terms are used. These are explained in non-technical language when first used. The first three chapters deal with fibers in general and should be thoroughly understood by the reader before he proceeds to the following ten chapters, each of which deals with a particular kind of fiber. One of the best features of the volume is the series of excellent plates showing magnified cross sections and profiles of various fibers.

OPTICAL INSTRUMENTATION, edited by George S. Monk and W. H. McCorkle. 262 pages, illustrations, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1954. Price, $3.75.

This is not a general text on optical instrumentation, but is mainly a collection of highly specialized papers on topics of importance to nuclear scientists. The editors give a brief survey of the problems associated with visual observation of areas that must be shut off by shielding. Then follow 37 condensed reports by members of the Optics Section of the Metallurgical Laboratory of the Manhattan District Project of the University of Chicago. The average length of these papers is five pages. Covered are such subjects as periscopes, borescopes, coloration of optical materials, plastic lenses, evaporation and sputtering of metals, and mirror preparation.

CURRENT TOPICS

World's Most Powerful Electron Microscope.—A new type of electron microscope, twice as powerful as any now in use, was recently displayed for the first time at the United Nations in ceremonies turning it over to the Karolinska Institute of Stockholm, Sweden.

The new instrument, developed and built at Camden, N. J., by the Radio Corporation of America, was formally accepted for the Swedish research center by Oscar Thorsing, Permanent Delegate to the U.N. from Sweden. The institute, renowned for its pioneering research in cell structure, is receiving the microscope under a grant from the Rockefeller Foundation.

The new microscope will permit study of particles smaller than one 10-millionth of an inch in diameter. Photographs taken by an automatic camera contained in the instrument can be enlarged up to 200,000 times the size of the specimen—a scale at which an ordinary dime would measure more than two miles across. The previous type of electron microscope, with which the polio virus was observed for the first time, normally provides useful photographic enlargements only up to 100,000 times.

Participating with Mr. Thorsing in the ceremony were Theodore A. Smith, Vice President in Charge, RCA Engineering Products Division, Albert F. Watters, of RCA's International Division, and Dr. Robert G. Picard, RCA scientist and president of the Electron Microscope Society of America, who designed and supervised development of the new model.

The new microscope differs radically in appearance from earlier types. Two desk-type working surfaces, each backed by a sloping control panel, flank the slender, 7½-ft. vacuum column that forms the heart of the instrument. The desk and control panel units are joined to the column at a slight forward angle to place all controls within reach of the operator, seated at a chair in the center.

Built into the column at desk level is a viewing chamber equipped with windows on three sides to permit several persons to see the enlarged specimens at the same time. The column below desk level houses automatic plate and roll film cameras that photograph the viewing screen from below. Practically all operations, including photography, are controlled by push-buttons.

The electronic microscope operates by directing a concentrated beam of electrons through the specimen, which is placed in a small aperture in the column about half way between the viewing screen and the electron gun at the top of the column. As the electrons pass down through the specimen they are affected in varying degrees according to the density and composition of the various parts of the specimen. When the beam emerges from the far side, it bears the pattern or "image" of the specimen, which is then magnified by magnetic lenses and projected on the viewing screen.

The ordinary optical microscope, using light to form the image of the specimen, is limited in its range by the wave-length of visible light. Objects appreciably smaller than this wavelength fail to interrupt or reflect the light in any visible fashion. The elec-

tron beam, however, has a wave-length only one 100-thousandth as great as that of visible light, with the result that it is interrupted or reflected by far smaller particles. The immediate effect of the electron microscope when it was first introduced, was to multiply by fifty times the range of human vision into the world of infinitely smaller organisms and particles. The new microscope has now doubled that range.

Among the major advances incorporated in the new instrument is its great increase in resolving power in the limit of magnification at which separate particles can be clearly distinguished. Additional improvements over earlier models are the simplified push-button operation of the new type, reducing the skill required of the operator and cutting down possibility of human error, and a flexible power supply permitting use of a stronger electron beam when greater penetration of the specimen is required.

Synthetic Fiber Made from Chicken Feathers.—Chicken feathers, a waste product of the broiler industry, may relieve the U. S. from one more problem of strategic materials controlled from behind the Iron Curtain, according to Raymond Stevens, vice-president of Arthur D. Little, Inc., industrial consulting and research firm of Cambridge, Mass. Speaking to a group of 250 business and industrial executives attending an ADL Product Research luncheon in New York, Mr. Stevens demonstrated paint brushes manufactured by the Rubberset Company using a new resilient synthetic fiber made from chicken feathers. In appearance these brushes are virtually identical with brushes composed of the customary Chinese hog bristle.

The basic problem which led to the present development is the unwelcome domination of Rubberset's chief raw material by an uncertain foreign source. Research, carried on jointly by Rubberset's Research and Development Department and the ADL staff, involved first locating this unusual new raw material and then, step by step, perfecting its complicated processing. Mr. Stevens gave credit to Laurence Hervey for leadership in the ADL part of the research program.

Paint brushes made from fiber derived from feathers are not yet on dealers' shelves. The Rubberset Company foresees some difficulties both in the manufacturing process and in convincing the user to change from the traditional product. No date for production beyond the present pilot-plant scale has yet been set.

ADL scientists have pointed out the chemical similarity between hog bristle and the new fibers. The new fibers are based on the protein Keratin, which forms a major part of wool, hair, fingernails, and the outer layers of skin; it is extracted from the chicken feathers by chemical means. The new product can be tapered, as bristle naturally is, to give a wide difference between butt and tip diameters; tapering makes for easy paint application. These two properties, in which the new fiber differs sharply from synthetics previously offered as bristle substitutes, are believed to account for its close approximation to the feel and painting properties of hog bristle.

Keratin in the form of a soft, insoluble cream-colored powder is itself an interesting new material and a welcome addition to the very short list of pure proteins that are or can be commercially available. Development of the powder was initiated by work carried on by the U. S. Dept. of Agriculture Western Regional Research Laboratories.

The powder is converted into bristles by a series of steps similar to those used

in the production of other man-made fibers. The powder is softened by chemicals and then, under heat and pressure, forced through small holes, which produce a soft thread. The threads are hardened and toughened in a series of baths. Keratin filaments are presently being manufactured in pilot-plant quantities by the Rubberset Company's Plastic Products Division at Salisbury, Maryland.

Accurate Hearing Test Instrument in Production.—An instrument which will provide the most reliable testing ever offered to the nation's 15 million hearing loss victims soon will be unveiled in Chicago. The Beltone Hearing Aid Company reported recently that its audiometer shortly will be in production after five years of laboratory and field research.

The manufacturer claims this testing unit is easier to keep in calibration than any previous audiometer, and that will be a major contribution to the success of group testing programs being conducted by more and more schools, industries, and hearing specialists. It can test up to 40 persons at one time.

The less than 14-lb. Beltone audiometer, reportedly the lightest made, is designed to surpass rigid American Medical Association standards.

Simplicity of design will mean easier operation and maintenance, as well as a 25 per cent reduction in price from previous levels. It uses only one tube and one voltage regulator. There will be no distracting clicking sounds when the hearing loss dial is turned. The instrument will have a calibrated masking tone, one bone conduction and two air conduction receivers for individual testing. For group testing, an automatic equalizer eliminates the need for deducting from dial readings.

Solar Battery.—A solar battery—the first successful device to convert useful amounts of the sun's energy directly and efficiently into electricity—was demonstrated recently at Bell Telephone Laboratories. Scientists there, with an amazingly simple-looking apparatus made of strips of silicon, showed how the sun's rays could be used to power the transmission of voices over telephone wires. The Bell solar battery also used energy from the sun to power a transistor radio transmitter carrying both speech and music.

Bell Laboratories reported that it was able to achieve a 6 per cent efficiency in converting sunlight directly into electricity. This compares favorably with the efficiency of steam and gasoline engines, in contrast with other photoelectric devices which have never been rated higher than 1 per cent.

With improved techniques the Bell Laboratories scientists said they expected to increase this efficiency substantially. Nothing is consumed or destroyed in the energy conversion process and there are no moving parts, so the Bell solar battery should theoretically last indefinitely.

The specially prepared silicon used is obtained originally from common sand, one of the world's most abundant materials. Silicon is a semiconductor, chemically related to germanium, the material used in most transistors. Silicon has a much greater electronic stability at higher temperatures than other semiconductors.

Although work is still in the laboratory stage, actual use of the solar battery in the telephone business is a strong possibility. For example, silicon solar batteries might be used as power supplies for low-power mobile equipment, or as sunpowered battery chargers which could be used at amplifier stations along a rural telephone

system such as that now under trial at Americus, Georgia. This system, using Bell-invented transistors, points to greatly increased service on rural telephone lines without the addition of new wires.

Although the sun supplies over a thousand trillion (1,000,000,000,000,000) kilowatt hours of energy daily—comparable with all the reserves of coal, oil, natural gas and uranium found on earth—man has never been able to convert more than a small fraction of this energy directly to his use.

Developed by a three-member team of Bell Laboratories scientists—G. L. Pearson, C. S. Fuller and D. M. Chapin, physicist, chemist and electrical engineer, respectively—the experimental solar battery uses strips of wafer-thin silicon about the size of common razor blades. These strips are extremely sensitive to light. They can be electrically linked together and can deliver power from the sun at the rate of 50 watts per square yard of surface.

Scientists have long sought a practical method of directly converting the limitless energy of the sun to electricity. Until now only the thermocouple and the photoelectric cell, limited by their natures to handling minute quantities of power, have been available. The thermocouple—used to regulate industrial furnaces—relies for its action on small temperature differences in two dissimilar metals. It is also used in astronomy, to measure the light from the stars. A common use for the photoelectric cell is in photographers' exposure meters.

Among the other silicon devices being studied at Bell Laboratories is a lightning protector for telephone lines which would be more compact and easier to maintain than those now in use. Also under study is a power rectifier, which can convert very large amounts of alternating current to direct current. An important feature of these is that they can operate at much higher temperatures than other crystal rectifiers now in use. All these devices when applied in the Bell System, where ruggedness, long life and reduced maintenance costs are significant factors, would offer numerous advantages over equipment now used.

Key to the new technique created at Bell Laboratories for producing these silicon devices is the controlled introduction of a foreign element into a microscopic layer near the surface of a thin slice of silicon. This process has been developed in the Laboratories by C. S. Fuller.

Treatment under gas at high temperatures permits the introduction of minute traces of impurities into the atomic structure at the surface of the silicon. Introduced at a precise rate and under carefully controlled conditions, the impurities reach a depth of less than one ten-thousandth of an inch. This is essentially a "p-n junction," which is the heart of all these devices and which, when built into a germanium single crystal, is the basis for the junction transistor, also invented at Bell Laboratories.

New Material for Making Die Models.—Ford Motor Company's Engineering Staff has developed the use of a new material for making die models and patterns which will speed the production of new cars. The material, known for some time but never before applied on a commercial scale in the automotive industry, also will result in a substantial time and cost saving, according to company officials.

The process involves the substitution of laminated and impregnated mahogany board for the plain mahogany board normally used to make the wooden models from which steel production dies are formed. The steel

dies are used in turn to punch and stamp out metal body parts for cars and trucks.

The mahogany veneer is impregnated with synthetic resins and laminated into board. This treatment greatly reduces swelling, shrinking and moisture absorption in the wood, and increases its resistance to heat. Ordinary wooden die models and patterns may swell or shrink so much between the time they are built and the time they are used that they require resurfacing. This not only is costly, but may result in loss of production by disrupting the precise timetable required for developing and manufacturing present-day automobiles.

Since the wooden models determine the shape of the steel dies, it is important that these models do not change dimensions from the time they are built until the steel dies have been copied from them. This period may vary from a few months to nearly a year. Because the processed wood, unlike the plain board, is only slightly affected by changes in temperature and humidity, much costly reworking of die models will be eliminated.

Due to the ability of the material to resist high temperatures, Ford Engineering Staff, using wood patterns made from it, has been able to produce successfully experimental precision moulded castings.

Feasibility of applying the new type of wood to the manufacture of wooden die models and patterns was proved during a year-long research program sponsored by Ford at the U. S. Agricultural Department's Forest Products Laboratory in Madison, Wis.

New Thermal Insulation.—How scientists of the General Electric Research Laboratory applied scientific principles to the development of an entirely new thermal insulation that is the most promising improvement in household refrigeration in years, has been disclosed by Dr. C. Guy Suits, GE vice president and director of research.

Dr. Suits told of the discovery of a new insulation for refrigerators, capable of reducing the present four-inch thick walls to only about a fourth of an inch, without reducing insulation efficiency. The new development in thermal insulation promises to be an outstanding application of fundamental science to a longstanding human problem—providing a benefit every housewife can understand and appreciate. The subject is one that has been studied by many of the world's leading scientists and technologists over many years. Up to now, with the exception of the thermos bottle and Dewar flask, the best thermal insulation found consisted of finely divided matter in either powder form or fibre form such as asbestos or glass wool.

"One of the important functions of such finely divided material in insulation," the director of GE research declared, "is to immobilize air. It is the circulation of air due to convection, which transfers most of the heat in insulation. Hence, if the air can be immobilized in the interstices of the insulation, the transfer of heat is prevented."

The principle of the thermos bottle was obviously far superior to any other fundamental yet known, Dr. Suits asserted, explaining that it couldn't be applied to a household refrigerator earlier because refrigerators have flat panels rather than self-supporting walls. The problem was to support these flat panels, without conducting appreciable heat, against the crushing strength of atmospheric pressure (more than a ton for each square foot).

"How to accomplish this seemingly impossible requirement was discovered recently in our laboratory by Drs. F. P. Bundy and H. M. Strong, " he said. "The result is going to have very important uses in industry and the home," he continued. "This new flat panel vacuum insulation is the most perfect heat barrier ever devised. It is from ten to thirty times more effective than the best flat insulation in common use, and in its best form, is three times better than the Dewar flask or thermos bottle."

High Speed Accounting Machines.—A new automatic high speed printing and accounting machine capable of turning out 27,000 punched card paychecks an hour, handling in the process up to 108,000 punched cards, has been announced by John S. Coleman, President of Burroughs Corporation.

Operating at a speed of over 43,000 characters a minute, the new line of machines, called the Burroughs Series G, has the fastest printing process yet developed for accounting purposes, Coleman said. It is also the first business machine equipment in which printing and simultaneous high speed punching can be accomplished in a single operation.

"The Burroughs Series G machines," Coleman stated, "are a milestone in the development of automatic high speed data processing equipment. Up to now, the application of electronics to clerical work has been seriously hampered by the inability of printing equipment to match the extraordinary speed of electronic computers. The printing process employed in the new Series G machines has made a major stride in bridging this gap and will broaden greatly the range of practical applications for electronic office equipment."

By synchronizing high speed totaling, printing and card punching, the Series G machines will integrate, in one fast operation, a number of separate steps in the accounting process, each one of which has traditionally been an expensive and time-consuming operation.

Principal applications of the Series G machines are expected to be found in public utility companies, publishing and mail order concerns, insurance companies, and other industries where there is a large volume of accounting records, promotional and mailing pieces.

In preparing utility bills, for instance, customer cards would be placed in one feed of the card reading unit, and billing information in the other. With one pass of the two sets of unmerged cards, the machine would produce a postcard bill with name and address printed on one side and meter readings, rates, dates and charges printed on the reverse side.

In the same operation, the stub would be punched with the account number and amount for the purpose of crediting the customer's account when payments are received; a separate punched card would be created for use of the meter reader on his next round; totals for proof and analysis would be provided and, if desired, a register would be furnished containing all the billing information.

In many companies, the different tasks accomplished by this single integrated run now require eight separate operations. The Burroughs Series G machine could have bills for over 2200 families ready for the postman every ten minutes.

By the use of the dual card feed in direct mailing operations, two name and address labels may be produced side by side simultaneously at a speed of 36,000 three-line addresses per hour. At the same time, the machine will be able to create punched cards on a selective

basis, if desired, for such purposes as follow up or special reference.

Insurance companies can print premium notices at the rate of 13,500 an hour with up to eight carbon copies.

The Series G machines are capable of feeding and reading two separate files of standard 80 column tabulating cards without the necessity of merging or collating.

Each of the machine's two card feeds operates at a speed of 900 cards a minute. The three reading stations in each feed allow multiple line printing from both cards simultaneously or selectively at the rate of 900 lines a minute.

High printing speed and the capacity to print in 48 alphanumeric printing positions have been achieved through the electronic decoding and analysis of punched cards.

Alphabetic, numeric and special characters are formed by wires in a 5 by 7 mosaic. Each wire is individually activated and positively driven in both directions (printing and restoring). The electronic decoder accepts the punched holes and selects the proper wires to form the desired character. High speed mechanical printing is thus accomplished by moving small masses of wires a very short distance (approximately 20/1000ths in.).

A feature of the machine's paper handling device is continuous form-to-form ejection of up to 2½ inches without loss of a printing cycle, and blank ejection at the rate of 25 inches per second.

The Series G machines will be able to create printed records not only in multiple copy continuous forms and individual sheets, but also in the form of punched tabulating cards.

Synchronized with the printer unit, the punching mechanism will make it possible immediately to punch any selected data from the two input cards, the accumulators, or from the digit emitters, directly into the same tabulating card document that has just been printed.

Card punching will be carried out in any of 40 columns and the punch unit may be used also as a high speed summary punch, reproducer, gangpunch and interpreter.

Electronic accumulating registers capable of adding, subtracting and crossfooting may be had in any quantity desired. Three classes of totals—minor, intermediate and major—are printed in net balance amounts.

Control of all printing, punching, accumulating and selecting operations will be accomplished by the wiring of removable plugboards. Class, digit and field selection is to be available in all 80 columns of each card and in all reading stations of each card feed.

The various units of the machine will be assembled to fit specific needs. The card reading unit, for instance, is available with either one or both feeds; the console decoder unit will be fitted with an electronic mechanism which makes possible as many printing positions as are required; the printing units are assembled, in multiples of four, to print from 28 to 48 characters per line; punching may be performed in any 40 columns that may be desired; and accumulators are to be available in multiples of four.

Up to three printing and/or punching units may be operated simultaneously from one dual card-reading unit.

On a long-range basis, the Burroughs Series G machines are not committed only to the use of punched cards. They can be readily adapted to other data handling media as they are developed and come into general, practical use.

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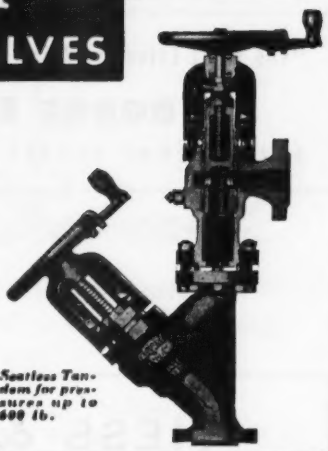

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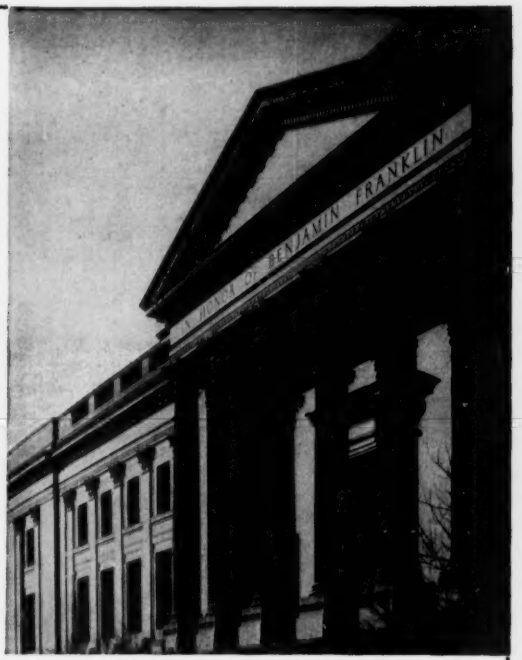

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